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PHYSICAL GEOGRAPHY.

FORM AND DIMENSIONS OF THE EARTH.

1. The Earth a Planet.—The Wise Men of old, dwelling in the lands where Astronomy had its birth, made two groups of the starry hosts which crowded their midnight skies. Five, of duller aspect, were observed to change their places from night to night, and year to year, and were called Planets—Wanderers. The rest, far more brilliant, "burning like torches with eternal flame," maintained their places unvarying from age to age, and were named Fixed Stars. Of the five, two were seen to be constantly in the near neighbourhood of the Sun, and always on the same side of the Earth with him; the other three moved away to all distances, and were often seen on the side opposite the Sun. In process of time it came to be known that the movements of these five were made round the Sun as a centre; and still later, that the Earth, instead of being fixed and having the heavenly bodies moving round it, as they appeared to do, itself really moved round the Sun in the same manner, having two planets within its orbit and three on the outside, and was therefore to be held as one of the planets. In our own time, the number of the planets has been increased by the discovery of 2 very large, and 105 very small bodies, which perform similar movements; and, so far as is yet known, there may be many more in a state of constant circulation round the central Sun.

2. Form of the Earth.—So soon as the idea got into men's minds that "the Earth was hung upon nothing," and that "none could tell whereon its sockets were fastened," it was an easy step to believe it round, and that the daily motion of the heavenly bodies about it was only an appearance caused by the revolution on its own axis. To such a motion, indeed, the spherical form seemed necessary. To an observer on its surface, it is true, the Earth does not at first sight appear to have this form, but to be a wide-spreading, irregular plain. When, however, intelligent observation and reflection are brought to bear upon the subject, it is perceived that the surface does not extend away indefinitely in all directions. From the pinnacle of a tower, from a mountain top, or mast-head of a ship, the surface of the Earth seems to come into contact along a circular line with the "heavens stretched out like a [tent] curtain," embracing on all sides the observer's position, and at no great distance from it. Beneath this line, on one side, the Sun is seen to disappear at different points from day to day and month to month, and, on the other side, at corresponding points to rise above it on the next day. The conclusion cannot be evaded that the Earth is of limited extent laterally and downwards, and of a roundish form.

The clearest evidence to the same purpose is obtained when we view distant objects on the surface of a wide level plain, or on the sea-shore. The tops of trees, or of buildings far off on the plain, come first into sight. As we advance towards them, we see more and more of them, till at length, when we are tolerably near, the whole object is seen from top to base. When a ship is approaching the land, we first catch sight of the topmost spars, and as she nears us, more and more of the mast and rigging come into view—at last the hull or body of the ship. Now, were the Earth an extended plain, the hull, as being largest, should come into view first, whereas it is the smallest part, which in that case should be seen last, that in the actual case becomes visible first. The sailor, in his earnest look-out for the hoped-for land, mounts into the cradle or the highest shrouds. To his straining eyes, the tops of the distant mountains are dimly seen rising over the waste of waters. As he advances towards them, they rise up more and more, then trees and buildings shew their tops, and at last the shore-line is seen with the playful waves leaping up along it. These appearances are noted on every shore, and in all directions. For if in two directions only, then might the Earth have the form of a cylinder, along which in one direction objects would appear exactly as on a plane surface; but since in all directions alike, then must the form of the Earth be spherical. The gradual rising higher up of the stars about the pole of the heavens, and the appearance of stars not seen before, as an observer advances northward along the Earth's surface, as from the south of Ethiopia to the north of Palestine, and the sinking down of those in the direction exactly opposite, were recognized in very early times as a proof of the Earth's sphericity. It was seen that this could not take place if the Earth were plane or cylindrical. The shadow of the Earth on the Moon, recognized in the earliest times as the cause of an eclipse, was seen to be always bounded by a circular arc; and no body, in any position it may have, can throw a circular shadow except a sphere. It was known also in very ancient times, that observers on different parts of the Earth did not all see the Moon in the same direction; and that eclipses of the Moon, seen from different parts of the Earth, take place at different times, with respect to midday at the places—the differences being proportional to the distances east and west.

Another proof of a direct, and, we may almost say, tangible character, has been furnished by modern enterprise. The great Southern Ocean, as conjecturally it was called, having been discovered in 1513 by Balbao, from the top of the dividing ridge

in the Panama Isthmus, Magellan, with his lieutenant, Sebastian Cano, started in 1519 in command of an expedition fitted out by Spain, crossed the Atlantic, worked down south along the South American coast, threaded his way through the tedious intricacies of the Strait that bears his name, and then steered boldly out north-west into the vast expanse of the great Pacific. Keeping a course west and north for five months, he touched first the Philippine Isles on the coast of China. Here he unwisely took a side in a native quarrel, and unfortunately lost his life. Many of his companions perished with him; but his lieutenant, Cano, escaping in one ship, the Vittoria, returned home through the Indian Ocean, and round the Cape of Good Hope, and reached San Lucar di Barrameda, from whence he had set out, in September 1522. Thus was the globe for the first time circumnavigated, the direction followed being constantly west. The voyage was next made by Drake, more than sixty years after; and now hundreds of vessels from Europe make it every year, going out eastward round Africa to Australia and New Zealand, and returning home round South America.

An argument for the Earth's form has been drawn from analogy with the heavenly bodies. The Sun, Moon, and planets, and, to all appearance, also the brilliants of the sky, though without visible discs, are globular in form; and the natural conclusion is, that the Earth, which has with them so many points of resemblance, is a globe also, allowance being of course made for the slight inequalities of surface, which are as nothing on a body of a magnitude so great.

The falling away of the surface of the globe at any point from the direction of a tangent at that point, that is, from a horizontal surface, is greater than would at first sight be supposed in regard to a body of so great dimensions. Let two points, A and B (Fig. 1), be taken on the surface of the sea, four miles apart, and conceived to be joined by the straight line ADB, the chord of the arc ACB, then the size of the sagitta, or versed-sine C D, perpendicular from the highest point, is easily calculated if the radius be known. It is found to be 15¾ inches in length. By so much is the chord depressed, and so quickly does the surface fall away from the direction of a tangent at the point C.—It may here be remarked, that by a *level* surface is meant, in engineering, such a surface as water will remain on without current, as the surface A C B of the sea or a lake; while a *horizontal* surface is one like the tangent plane at C, or one parallel to it.

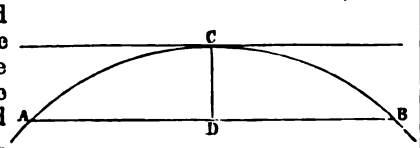


Fig. 1.

3. Such a figure from its simplicity, and what was called its "perfection," recommended itself to all as the Earth's form. Sir Isaac Newton was the first to shew that the Earth had not this "perfect" form —that it was not a sphere, but a spheroid, that is, like a sphere, but flattened all round towards the poles, and protuberant at the part intermediate. He had recently established the theory of universal gravitation; and the laws of centrifugal force had been investigated, partly by Huyghens in 1663, and partly by himself. This latter force, which plays so important a part in celestial mechanics, is developed in every case of curve-lined motion about a centre, and of revolution on an axis. In this latter case, the particles remote from the axis of motion acquire a tendency to fly off from it—so strong under great velocities, that such bodies as grind-stones and fly-wheels are torn to pieces. Combining these theories, Newton proved, in one of the most profound and wonderful investigations of the *Principia*, that if a perfect sphere be constituted of materials of uniform density, and capable of free yielding, and be made to revolve on an axis, it will become flattened all round at the parts near the ends of the axis of revolution, that is the poles in the case of the Earth, and protuberant at the parts most remote from the axis, or at what we call the equator on the Earth. He shewed that the amount of flattening and protuberance depended on the velocity of rotation, and that the process would go on, beginning from perfect sphericity, until a certain amount of flattening and protuberance was established. M'Laurin afterwards proved (1743) that the Earth's actual figure, an oblate spheroid, was a form of permanent equilibrium.

The theory of the Earth's figure has been completed by the researches of Clairault (1743), and by those of Ivory in our own time. Newton also shewed that the same spheroidal form belonged to the bodies of the planets, and that the polar compression was greatest in those which had the swiftest rotation on their axes.

4. Newton shewed, moreover, that it was a necessary consequence of this figure, that the force of gravity should be least at the equator, and should increase regularly in intensity towards either pole, according to a fixed ratio which he stated, namely, the square of the sine of the latitude. The weight of a body thus undergoes a progressive increase, till at the pole it reaches $\frac{1}{289}$; that is, a body which at the equator would weigh 590 lbs. would, from this cause alone, weigh at the pole 591 lbs.—such weight being estimated, of course, not by a pair of balances, but by some other contrivance, as a delicate spring. If it were possible to observe accurately the velocities of bodies falling from a given height, in different parts of the Earth, the varying force of gravity would be shewn in the most simple and satisfactory way; but these differences escape the closest observation, and recourse is therefore had to the oscillations of a pendulum. Now these are produced by the force of gravity. When the pendulum is drawn from the perpendicular direction, it falls towards it again, and the velocity so acquired carries it out to the distance fallen from; gradually retarded by the same force, it rests for an instant, and then returns, to rise on the other side; and so on continually for a long period, if delicately suspended in a space free from the air's resistance. At any given place a short pendulum oscillates quicker than a long one, so that hot weather, which expands a pendulum, makes it move slower; and so a clock loses in such weather, while in cold it gains. If from any cause the force of gravity is increased, the pendulum must be lengthened so as to make it

perform its oscillations in the same time; while, if the force gets less, then must the pendulum be shortened. Hence the vibration of a pendulum in different latitudes will indicate the varying intensity of terrestrial gravity. Newton suggested this mode of testing the Earth's form. When it was tried, his theory in regard to the Earth's figure was completely confirmed; and the coincidence of theory and observation is one of the strongest arguments, both for the form and axial motion of the Earth.

The pendulum is, however, subject to another influence. The centrifugal force developed by the Earth's rotation, which amounts to more than 1000 miles per hour at the equator, and to half as much in lat. 60°, acts in opposition to gravity, giving bodies a tendency to fly off from the Earth. Weight is thus taken off a body, that is, it is rendered lighter by a certain part of its whole weight. The fraction expressing this amount of *lightening* of a body, was found by Newton to be $\frac{1}{289}$th of its whole weight, that is, the centrifugal force is $\frac{1}{289}$th part of the force of gravity. Now it has been above stated, that owing to the spheroidal form of the Earth, the weight of a body is increased by $\frac{1}{193}$th part at the pole; the two causes together make an increase of $\frac{1}{578}$th of the whole, this fraction being the sum of the other two. So that a body which weighs 194 lbs. at the equator, will weigh 195 lbs. at the pole.

5. Dimensions of the Earth—Early Measures.—The method of determining the dimensions of the Earth by the measurement of an arc of the meridian is that which has been employed, without any alteration in the principle, from a very early time up till the present day. It was perceived that if the number of degrees between two points on a great circle of the sphere could be found, and the distance of the points determined in straight-lined measure, a simple multiplication would give the distance round the Earth, and thence the diameter easily. It is impossible to measure such an arc of the meridian on the Earth itself directly; but the rapid changes in a star's elevation above the horizon, and in its distance from the zenith, as an observer passed either north or south of any place, suggested a method of doing it. All circumferences being divided into 360°, if lines be drawn from the centre cutting off arcs of concentric circles, the arcs between the lines will be the like aliquot parts of the two circumferences; so that if A B (Fig. 2) be an arc of the Earth's surface, and Z D an arc of the heavens,—or the amount by which a star is displaced from the zenith Z, when an observer moves from A to B,—and if the number of degrees in Z D is measured, the same number of degrees will be in the arc A B of the Earth's surface, considered as an unbroken curve, like the surface of the sea. In the same way, if an observer change his place on the Earth from *a* to *b*, and the difference S S′ of the meridian altitudes of a star be measured, the arc *a b* becomes known. The most perfect instrumental means are now employed to do this. A Hadley's quadrant or sextant is employed to measure altitudes. An image of the celestial object *t* is seen at *t′*, either below a smooth water-horizon, N R, or in a false horizon placed there, as a levelled mirror or vessel of quicksilver, and the arc *t t′* is then measured; the half of this is the altitude *t* R. Zenith distances are measured by an instrument called the zenith-sector. A telescope, A B (Fig. 3), swings upon pivots C, D, with a graduated arc attached below, across which a plummet D P, connected with one of the pivots, swings freely, marking off degrees, minutes, and seconds on the arc E F. In this way the star's angular distance from the vertical, that is, the star's zenith distance, is ascertained.

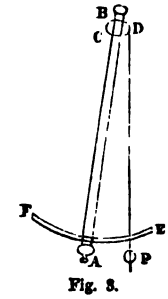


Fig. 3.

From the foregoing considerations, it is manifest that if the curvature of the surface along a meridian be not uniform, but less or greater in one part than in another, equal distances passed over will not equally displace a star. If the surface is flatter, approaching more to a plane, a greater space must be passed over to displace a star by a certain amount, than if the surface had preserved its usual curvature. If the surface become more curved, the distance to be passed over will be less. Conversely, when an observer finds that he has to traverse a longer distance on a meridian in one part than in another to produce the same displacement, he will know that the meridian is there flatter. It was in this way that the flattening of the meridians in Lapland and their protuberance in Guiana were actually measured.

The first attempt to find the size of the Earth was made about B.C. 230, by Eratosthenes, a philosopher of the Alexandrian school. He employed the zenith distance Z D of the Sun to determine the number of degrees in the arc A B of the meridian (Fig. 2). He observed that at Syené, on the confines of Nubia, the Sun was vertical at noon on the day of the summer solstice, inasmuch as the edge of a deep well did not throw a shadow on the bottom. At Alexandria, taken as due north of Syené, he ascertained by means of a style casting a shadow on a graduated surface, that the Sun at the same hour of the longest day was 7° 12′ distant from the zenith towards the south. The distance between the two places he made 5000 stadia. Now, the arc of 7° 12′ is one-fiftieth of the circumference; hence, the Earth's circumference was made 250,000 stadia; whence he readily found the diameter by the proportion of 7 to 22, and hence the bulk of the sphere. We cannot tell how near this estimate was to the truth, as we do not know the length of the stadium which was employed, there having been several measures of this name in use. Besides, the measure of the zenith distance was rude, in fact 11′ in error, and the two places are not on the same meridian, Alexandria being 3° farther west. Ptolemy, 367 years later, speaks of 1° as 500 stadia in length; of which again we can make nothing, since the length of this stadium is unknown also.

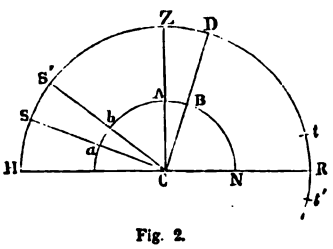


Fig. 2.

6. Other Measures.—In 1528, Fernel determined a point 1° north of Paris, and measured the distance by the revolutions of a wheel—the error in his estimate being no more than 2000 feet. Snell was the first in 1617, to discard such itinerary measures, and to use trigonometrical calculation. His estimate was a very good approximation; but it required all the instrumental improvements of modern times, a knowledge of various astronomical corrections, as well as the improved methods of calculating, introduced with the invention of logarithms (1614), to enable mathematicians to grapple with the difficulties of the problem. Fortunately Columbus, in entering on his great enterprise, underestimated the size of the Earth and the breadth of the Atlantic. He seems to have taken the estimate of a degree made in A.D. 814, under authority of the Caliph Almamoun, which was 56⅔ miles. Unfortunately Newton made a like mistake. Ignorant, apparently, of the determination of Snell, he took a degree at 60 miles, and his investigation for identifying terrestrial gravity with the force urging the Moon every instant in a curve-lined path came out erroneous. It was not till several years after, that, being made aware of the measure of Picard in France (1670), which gave 1° equal to 69$\frac{1}{6}$ miles, he resumed his calculations, and identified the forces (Brewster, Life, I., xii., 290).

7. Arcs of Meridian—Triangulation.—All the refined methods of modern science have been recently applied to the solution of this problem, and arcs of meridian have been most accurately measured in various countries.—From a given station an arc is laid down approximately north and south. An observer having an astronomical clock beside him, beating loudly and clearly, observes with a transit telescope placed nearly in the plane of the meridian, the instant of the greatest elevation of Polaris above the pole; and again, the instant of the star's greatest depression below the pole; if the interval is exactly twelve hours, the axis of the instrument bisects the diurnal circle in which the pole-star moves around the pole, and is therefore precisely in the plane of the meridian; if not, a few observations and adjustments will suffice to place it so. The axis of the instrument is then in the plane of the meridian, and thus an arc of this circle can be accurately laid down upon the surface. Two points on the meridian are thus determined; and now their distance apart in degrees, minutes, and seconds is found, by measuring the corresponding celestial arc with the zenith-sector by means of the displacement of a star. It may also be determined by taking the difference of latitude of the two places. Thus is found the required arc, whose length in yards must now be measured.

The accompanying figure and brief explanation will help to convey some idea of how this is done.

At or near one end of the arc, a base, A B (Fig. 4), of four to seven miles, is measured on a hard level surface, with the utmost exactness, by help of all the refinements of modern invention. A number of stations or signals which may be objects in the landscape or set up on purpose, are taken along the arc and on opposite sides of it, each being visible from two others. The whole district is then covered with a network of triangles. The angles B A C, B A *a*, A B C, are measured with a theodolite. A B being known, A C, B C, and A *a*, B *a*, are calculated by trigonometry; now A *a* is the first portion of the arc of the meridian. Taking again the signal D, the angles B C D, C B D are measured; and B C being now known, B D and D C are computed; also the angle B *a b* is measured, and *a b* computed, which is another portion of the arc; and so the work proceeds till the arc is found piecemeal. It is often more convenient to determine parts of the meridian by means of parallels, such as F D. If this line is calculated, the portion, *x y*, of the arc cut off by perpendiculars from F and D is known, and so of others. In order to check the accuracy of the work, two or more bases, as F I, R E, are carefully measured in the same manner as the first base, and brought into the triangulation, and when the work reaches them they are calculated. If the length thus found agree with the measured length, the accuracy of the work is proved; if not, the angles measured and the calculations are overhauled till the error is found and agreement effected. These lines are called bases of verification. In the great triangulation in France in 1740, as many as seventeen such bases were measured. A general triangulation of a country for the purposes of mapping is conducted in exactly the same way; the areas of the triangles being then found. Now, in consequence of the irregularity of surface, and the positions of the stations at various heights, the triangles are not all in one plane, and the angles are not therefore horizontal angles, which they are required to be, since the lines and triangles are supposed to be on the surface of the sphere. They are reduced to horizontal angles by applying a simple mathematical formula, from which tables of easy use have been constructed. But these horizontal angles are the angles of spherical triangles, and so spherical, not plane rectilineal angles. Hence a correction must be applied to reduce them to the angles of a plane triangle of the same sides, and equal in area. The sides may therefore be taken as if the triangles were plane, and the area calculated on this supposition. The area will then differ from that of a plane triangle, by a quantity scarcely appreciable, even in triangles whose sides are more than 100 miles. For the sake of accuracy, however, the correction given by a simple formula is applied. The triangles forming such a connected system in the same country are at different levels, and the surveys have been made in different regions at various levels; but to give us a just notion of the form of the Earth, and to have the areas accurate, there must be one surface of general reference. This is, of course, the surface

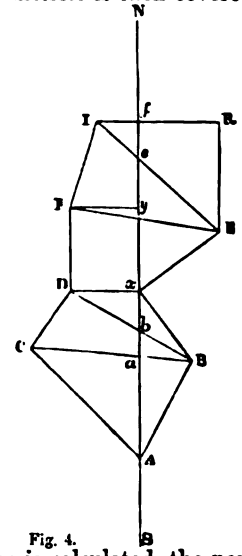


Fig. 4.

of the sea, or rather the surface which would be found by producing the plane of the sea under the lands. With this constant level a sphere is conceived to be described, on the surface of which all the distances and triangles are supposed to be projected. All distances measured on the Earth's surface are reduced by computation to this standard level.

8. Arcs of Parallels.—Since the Earth revolves on its axis in 24^h, 15° will pass under any celestial meridian in 1^h, and 1° in 4^m, so that places differing 15° in longitude differ 1^h in time, the time being *earlier* or *less advanced* the further *west* the place is. The extent of an arc of a parallel is determined on this principle. The time of a star's transit (Art. 5) is observed at two places on different meridians; the difference of time turned into degrees, minutes, and seconds, is the arc of the parallel, or difference of longitude. The arc is then calculated by a triangulation, as in the case of a meridian. The Earth has thus been found to have the same form under all the meridians where arcs have been measured; and the degrees are found to decrease towards the poles according to a definite ratio. The length in any latitude may be calculated by this proportion—

As rad. : cos. lat. : : 69·04 miles : length of 1° long. in that lat.

To determine the difference of the times of transit at the two places is the only difficulty—clocks must be compared to the utmost degree of accuracy. There are various ways of doing this: gunpowder is exploded along a line of stations on the arc, so that each explosion is visible from two stations on opposite sides, the light being seen at the same instant at both; the difference of the clocks is the difference of longitude, if both are correct in shewing their own local time. The instant of the transit of a certain star at Paris is telegraphed to Greenwich. When the star arrives at the celestial meridian of Greenwich, the instant of time is telegraphed to Paris; the difference of the times of transit is the difference of longitude, supposing the transmission instantaneous, that is, that the electric fluid travels *in no time*. In measuring the arc between Greenwich and Valentia in Ireland the Astronomer-Royal had thirty chronometers carried backwards and forwards twenty-two times. The interval of transits, or difference of longitude, was thus found to be $41^m\ 23^s$; the arc was then calculated by trigonometry. The circumference of the Earth at Greenwich is then found by the proportion—

As $41^m\ 23^s$: 24^h : : length of this arc : Earth's circumference at Greenwich.

9. Statistics of Form.—The following are the dimensions of the Earth deduced from all the measurements :—

Equatorial diameter, 7925·648 miles = 41,847,426 ft. or 7926 miles
Polar do., 7899·170 ,, = 41,707,620 ft. ,, 7899 ,,
Difference or polar comp. - - - } 26·478 ,, = 139,806 ft. ,, 26½ ,,
Ratio of diameters, - 299 to 298 or $\frac{1}{299}$ of the greater.
Circumference on a great circle, 24,899 miles.

The late English survey made the Earth's diameter at 7900.

The following are the lengths of a degree in different latitudes :—

Latitude.	Length 1° lat. in Ft.	Latitude.	Length 1° lat. in Ft.
Peru, 1° 31′s.	362,808	America, 39° 12′N.	363,786
India, 12 32N.	363,013	France, 44 51N.	364,535
,, 16 8N.	363,044	England, 52 35N.	364,971
Africa, 33 18s.	364,713	Lapland, 66 20N.	365,782

The extreme difference is 2974 feet, or 334 feet less than half a mile. The mean length, that at lat. 45° in France, is 69·04 English miles; the length in Lapland is 1247 feet more than the mean; and in Peru, 1727 feet less than the mean. It is easy to remember that in England a degree is 29 feet less than 365,000 feet; and that 1″ of the curved surface is 101·38 feet. The metre, the French standard of lineal measure, is the ten-millionth part of the terrestrial quadrantal arc (90°), that is, 3·281 English feet.

The following table gives the lengths of 1° of longitude in different latitudes in statute miles, calculated by the proportion given above :—

Lat.	Stat. M.	Lat.	Stat. M.	Lat.	Stat. M.	Lat.	Stat. M.	Lat.	Stat. M.
10°	67·95	30°	59·75	50°	44·35	65°	29·15	80°	11·98
15	66·65	35	56·51	55	39·58	66	28·06	85	6·00
20	64·84	40	52·85	56	38·58	70	23·60	89	1·21
25	62·53	45	48·78	60	34·52	75	17·86		

10. Approximate Methods.—There are several methods by which single observations afford the means of finding an approximate value for the Earth's diameter. Suppose B C (Fig 5) to be the height of a mountain $2\frac{1}{3}$ miles high, and that the top B is just visible from the point D, 136 miles off. Then if we produce B C through the centre to A, draw the tangent B D, and join C D, A D, we have two similar triangles,

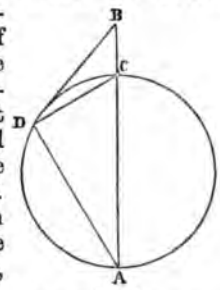


Fig. 5.

since B is common, and (Euc. III., 32) A = B D C; hence A B : B D : : B D : B C; or A B : 136 : : 136 : $2\frac{1}{3}$; therefore $2\frac{1}{3}$ A B = 18496, or 7 A B = 55488, and A B = 7927 nearly; subtracting $2\frac{1}{3}$ from this we have the diameter C A = $7924\frac{2}{3}$ miles.

Again, it is found that two points, A and B (Fig. 6), raised 10 feet above the water at *a* and *b*, cease to be visible each from the other at about 8 miles. Thus A D and D B being each 4 miles, we should have as in the last case—

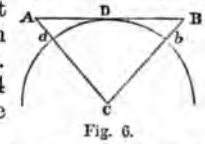


Fig. 6.

Diam. + A *a* : 4 miles : : 4 miles : 10 feet. Hence, neglecting A *a*, diam. × 10 = 21120 × 21120, and dividing by 5280, diam. = 8448 miles, an excess of 548 miles; but the method is not capable of any certainty, owing to the irregularity of the horizontal refractions.

11. Density of the Earth.—The terms Density and Rarity are used to denote the degree of closeness of the particles of bodies. They are estimated by comparing the weights of equal bulks of the bodies—the body which weighs most has the greater density. Thus ebony and mahogany are dense woods, corkwood very rare. If equal volumes

be taken of platinum and hydrogen, both metallic—the one the heaviest, the other the lightest known body—the one weighs 240,000 times more than the other, or contains so many times more matter, or greater mass. Distilled water is the standard of reference for all bodies; and the weight of a body in reference to that of an equal bulk of this standard is called its specific gravity. Specific gravity is then the weight of a unit of volume, density the quantity of matter or mass in a unit of volume. A solid is first weighed in air, then in distilled water, from which it displaces its own bulk, and the loss of weight is the weight of the displaced water. The number of times that this is contained in the weight of the body is its specific gravity; or use this proportion:—As the loss : 1 : : weight in air : specific gravity.

The stony layers forming the Earth's crust are found to have rather more than 2½ times the density of water; but the density must increase towards the centre, where the condensation will be greatest. The law of variation is not known; but assuming a law of increase for the successive elliptic layers, which should be consistent with pendulum experiments and astronomical influences, Clairault deduced a mean density for the Earth 5 times greater than that of water. This estimate was made before the problem was attacked by direct observation or experiment.

Schiehallion Estimate.—The first attempt of this kind was made in 1774 on Schiehallion Mountain in Perthshire, whose isolated position and abrupt form presented facilities for the exercise of an independent attractive effect upon a plummet, and determination of a cubic mass for comparison with that of the Earth.

Two stations were taken on opposite sides of the mountain, nearly on the same meridian, and their distance apart found by triangulation, two bases having been measured in the valleys below. Now the inclination which two plumb-lines ought to have to one another at this distance, owing to the curvature of the Earth, if no mountain intervened, is 1″ for 101·38 feet (Art. 9). The distance in this case was such that the inclination due to it was 41″·4. Observations on the same stars at both stations, made with the zenith-sector as before explained, gave a difference of 53″ for the *actual* inclination of the plumb-lines, that is, the actual difference in the direction of gravity at the two stations; the difference 11″·6 is due to the attraction of the mountain intervening.

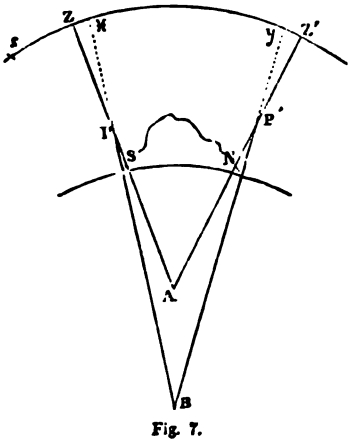


Fig. 7.

In the annexed figure (Fig. 7), P B, P′ B are the directions of gravity perpendicular to the arc, N S, of the Earth's surface, if no mountain intervene; P S A, P′ N A the actual directions, the mountain intervening. With the zenith-sector, to which the plummets are attached, the degrees in the arc Z Z′, or in the angle A, which that arc measures, are found. These express the change in the stars' zenith distance between the stations, or the difference in the actual direction of gravity. Thus the arc Z Z′ or angle A is 53″, the arc $x\,y$, between the dotted lines, 41″·4; so that the difference of the arcs, or of the angles A and B, is 11″·6, due to the attraction of the mountain.

By a careful survey the mass of the mountain was found in cubic miles; to determine its attraction, it was conceived to be divided into a great many vertical columns, the attraction of each of which was carefully estimated by a peculiar mathematical process, and from this it came out that the sum of the attractions of the mountain, from opposite sides, was represented by the number 8811⅔. Now the attraction of a sphere (and that of a spheroid will not differ) on a body at its surface is known to be $\frac{2}{3}\,d \times \pi$, where d is the diameter of the sphere, and π is the number 3·1416. But $\pi\,d$ is the circumference to the diameter d, and taking the Earth's circumference at 24,864½ miles ($69\frac{1}{15}=1°$), $\pi\,d$ is 131,284,080 ft.; hence the attraction of the Earth comes to be represented by the number 87,522,720. Now its density and that of the rocks of the mountain being supposed the same, their attractions are as 87,522,720 is to 8811⅔, or as 9933 to 1 nearly. But by the mathematical method, whereby the attractions of the prisms were estimated, we have the following analogy:—

As attrac. of earth : sum of atts. of hill : : rad. : tan. 11·6″,
or attrac. of earth : sum of atts. of hill : : 1 : ·000,056,239.

This last ratio is, in integers, very nearly 17781 : 1. Allowing for the centrifugal force of the Earth on its axis, this ratio becomes 17,804 : 1. This ratio results from actual observation, the other from the supposition of equal densities; the ratio of these two results will be the true ratio of the densities; this is, therefore, 17,804 : 9933, or 1434 : 800, or 9 : 5 very nearly. Now if the average density of stone be to that of water as 2½ to 1, we have, by compounding the ratios 9 : 5 and 2½ : 1, 22½ : 5, or 4½ : 1. But the survey gave 2¾ for the average density of the Schiehallion rocks; hence, by compounding the ratios 9 : 5 and 2¾ : 1, we have for the final result of this celebrated enquiry, the ratio 99 : 20, or 5 : 1 very nearly, for the relative density of the Earth and water.

Cavendish Experiment.—Mr. Cavendish, the discoverer of the composition of water, made the Earth's density the subject of experimental enquiry in 1798, by a method of great elegance. Dr. Reich and Dr. Francis Bailey repeated the experiments with considerable improvements, and increased precautions.—Two large leaden balls were brought into the near neighbourhood of two delicately suspended small ones, first on one side and then on the other, in such a way that nothing could disturb the small balls but the attraction of the large ones. A deflection in both cases was observed. This gave the intensity of the deflecting force and its ratio to the

weight of the balls. The attraction caused the small balls to vibrate through a minute arc. The ratio of this was observed and compared with that of a pendulum, whose movement is due to the same cause; and thus the relative intensities of the two attractions were estimated. Lastly, knowing the distance of the small balls from the large ones and from the Earth's centre, the size of the large balls and of the Earth, we can calculate what ratio the attraction of the large balls on the small would have to the attraction of the Earth on the small balls, on the supposition that the balls had the mean density of the Earth. This was found *less than* the attraction computed from the observations, and hence the density of the Earth was *less than* that of lead, in the same ratio. The mean density of the Earth was thus found to be 5·67, a little greater than that given by the Schiehallion observations.

Harton Colliery Experiments.—In 1854 experiments were made at Harton coal-pit, near South Shields, by the present Astronomer-Royal, to determine the Earth's density. Two detached pendulums, by whose mode of suspension friction was almost entirely done away with, were set up, one at the top and the other at the bottom of a vertical shaft 1260 ft. deep, and the times of vibration carefully observed by means of an astronomical clock placed beside each. The exact times of the successive coincidences of the vibrations of the detached and clock pendulums were carefully noted, by help of several nice contrivances to aid observation; this was done simultaneously at both stations, and the rate of each pendulum compared to its own clock determined. To ensure accuracy, the detached pendulums were interchanged at the two stations. The comparative rates of the two clocks were also found by means of telegraphic signals up and down the shaft. The exact times of vibration of the detached pendulums, at top and bottom, were thus accurately found, and this gave the ratio of the force of gravity at the two stations. The lower pendulum made $2\frac{1}{2}$ oscillations more in twenty-four hours than the upper one, and the force of gravity at the bottom exceeded that at the top by $\frac{1}{19189}$th part. The rocks of the surrounding country, and the strata of the elliptic shell between the two stations, were carefully examined in respect to their specific gravity; and as the result of the whole enquiry, the ratio of the mean density of the Earth to that at the surface was found. The mean density deduced was 6·565, which Mr. Airy maintains to be as worthy of credit as any of the others.

Experiments at Arthur's Seat.—During the early part of the trigonometrical survey of Scotland, Colonel Sir Henry James found a deviation of the plummet in the low ground at the base of Arthur's Seat, near Edinburgh, amounting to two seconds of arc; and hence deduced the Earth's mean density to be 5·316—a result more in agreement with the Schiehallion observations and the experiments of Cavendish, than with those at Harton Colliery.

12. Weight of the Earth.—Taking the dimensions of the Earth as already given, the mass will be 259,800,000,000 cubic miles, and as each cubic mile contains 147,200,000,000 cubic feet, there will be in all 38,242,560,000,000,000,000,000 cubic feet; and adopting Bailey's estimate of the mean density from the Cavendish experiments, each cubic foot, on an average, will weigh 5·67 times as much as a cubic foot of water, that is, $62\frac{1}{2}$ lbs. × 5·67, or 354 lbs. 6 oz. avoirdupois. Multiplying the number of cubic feet above by 354·375, we find the entire weight of the earth in lbs. to be 13,552,207,200,000,000,000,000,000, which is equal to 5,425,092,500,000,000,000,000 tons.

Very little is known regarding the effect of pressure in condensing stony substances. From the known effects of artificial pressure on liquids and gases, it has been conjectured that at the depth of 4 miles, air, by its own incumbent weight, would be as dense as water; that water at 93 miles would have its density doubled, and at 362 miles would be as dense as quicksilver; that at the Earth's centre, steel would be compressed into $\frac{1}{4}$th of its bulk, and stone into $\frac{1}{3}$th. The lunar inequalities forbid us, however, to suppose that the central condensation can be as great as this; precession and nutation, that the deep interior can be in a state of liquid fusion. None of the phenomena are opposed to the hypothesis that great reservoirs of melted matter may exist at a moderate depth below the surface.

Latitude and Longitude.

13. Latitude.—In traversing the ocean the navigator has to determine his precise position every day if possible, sometimes oftener, by observation of the heavenly bodies. The explorer of new lands finds a like but less pressing necessity. From these observations corrected for parallax, semi-diameter, refraction, and dip, the latitude and longitude are deduced by easy calculations.

a. **Parallax.** — A few of the heavenly bodies which are nearest to us, appear in different positions when viewed from different parts of the Earth (Art. 2), and it has been agreed to refer their positions to a common station or point similarly situated for all observers. This point is the Earth's centre. The position of a body as it would be seen from the centre, is its true place; its position as seen from the surface, its apparent place. All calculations refer to the true places.

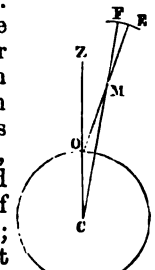


Fig. 8.

A body M (Fig. 8), seen from the surface of the earth at O, will appear among the fixed stars at E; if seen from the centre, it would appear upon the same sphere at F, so that it appears to traverse, or be displaced through, the arc E F. Now this arc, described from the centre M, is the measure of the angle E M F, or of its equal O M C; and O M C is the angle subtended at the body by the Earth's radius O C. This angular displacement of the body is its parallax. Parallax is thus the angle subtended at a body by the Earth's radius; its effect is to depress a body, to make the apparent place lower than the true; it is therefore an additive correction for all observed altitudes, and of course subtractive for all zenith distances.

Parallax increases towards the horizon, where it is greatest, and diminishes towards the zenith, where it is nothing.

b. **Refraction.**—A ray of light in passing from a rarer to a denser medium is bent at the point of entrance towards a perpendicular to the surface at that point; but if the medium entered be less dense, then the bending is away from the perpendicular. The bending of the ray is called Refraction. It increases with the obliquity of the ray; but if the ray enter perpendicularly, there is no refraction. This law of light is well illustrated by letting a ray, admitted through a hole in a window shutter into a dark room, fall upon a bason of water; a spot of light is seen on the bottom, and the bending of the ray at the surface. If a sixpence is placed on the bottom of an empty bason, and the eye withdrawn till the edge just hides it, then when the bason is filled the bottom will be seen to be very much raised. Hence water viewed obliquely appears much shallower than it is. A ray passing from free space into the Earth's atmosphere, traverses a medium whose density changes continually; the direction of the ray will also change continually, and so it will be bent into a curve line. A ray from a star S, in the annexed figure (Fig. 9), has a rectilineal path, till it enters the atmosphere at *t*; its course is then gradually bent into the curve line *t* A. Now we see objects in the direction the ray has when it enters the eye; but the direction of a curve at any point is that of a tangent at that point; hence the star is seen in the direction of a tangent A H, and so is elevated by the refraction of the atmosphere. Refraction is therefore to be subtracted from all observed altitudes, and added for zenith distances. Refraction takes place only in a vertical circle, since the density varies in that direction only. Like parallax, it is zero at the zenith, and increases towards the horizon, where it is greatest. So uncertain is it at all altitudes, that it has been called "the plague of astronomers." The mean refraction at 45° altitude is about 57½″; the horizontal refraction is about 33′, and thus we actually see the Sun and Moon while yet fully half a degree below the horizon. So great is it in certain states of the atmosphere, that the lower limb of the Sun near the horizon is refracted 5′ more than the upper limb; hence the vertical diameter is shortened, the other remaining, of course, unaltered, since the refraction is only in a vertical direction. The Sun thus appears of an oval form, or lengthened out horizontally; and the same takes place with the Moon. Since the air's density varies with temperature and pressure, the state of the thermometer and barometer must be taken into account in estimating refraction.

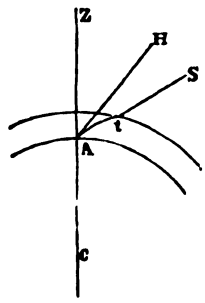


Fig. 9.

So long as the Sun is not more than 18° below the horizon his rays still strike the atmosphere, and are refracted by it, and diffused by reflexion from its particles and those of floating bodies, and so cause twilight. In our latitudes the Sun's path near the horizon is oblique to it; in tropical regions, nearly perpendicular to it. Hence twilight is long with us and short in those regions. In latitude 56° there is *no night* from May 5th till August 8th; within the polar circles, no sunset for nearly 3 months; total darkness for 77 days.

It is usual to explain the blue colour of the sky by the retention and diffusion of the weak violet rays, by the thin air aloft; the red colour of the Sun and Moon near the horizon, by the absorption of all the rays except the red, whose momentum enables them to pass through, and reach the eye. It is more probable, however, that the blue colour is due to reflection from excessively minute particles held in suspension. In a vista formed by trees, or by a row of houses and trees, the blue colour plainly comes out; and from the tops of very high mountains, the sky overhead is intensely blue.

c. **Semi-diameter.**—In observing altitudes of the Sun and Moon, the lower limb is used; hence the semi-diameter (15′ to 16′) must be added to find the altitude of the centre.

d. **Dip of the Horizon.**—From the shore of the west bay of Dunoon, the top of Ailsa Craig, 47 miles distant, and 1114 ft. high, just appears above the surface of the sea; from the Castle rock, 60 ft.


Fig. 10.

high, a considerable portion is seen; from Dunan hill, 575 ft. high, much more appears; on ascending to Bishop's Seat, 1651 ft. in height, and using a telescope, one can see the waves leaping up against the base of the rock.—To find the limit of the visible horizon *in miles* nearly, to the height of the eye *in feet* add half of that height, and take the square root of the sum. If the eye be 6 inches above the surface of water, this limit is ·866 of a mile; if 6 ft., 3 miles nearly, that is, a floating object at that distance is just visible. If the eye is 100 ft. above the surface, the limit is 12¼ miles; if 2400 ft., 60 miles; from Mont Blanc, 15,810 ft. high, 154 miles; from Chimborazo, 22,700 ft., 184 miles. If a point B (Fig. 11), be elevated above the general surface at O, the horizon of an observer at this height is depressed, his view is more extended; his apparent or visible horizon will be now QS, parallel to the sensible horizon but lower, being the base of a cone whose surface touches the earth all round, has its vertex at his eye, and passes through E, the utmost visible point. Any of the angles K B A, B E S, B A O, measures the dip due to the height B. The altitude of a body is thus increased, and the dip is subtractive. Hence, if A be any observed altitude, we shall have, by denoting the corrections by the first letters of the words, A + *p*—*r* + *s*—*d*=true altitude.

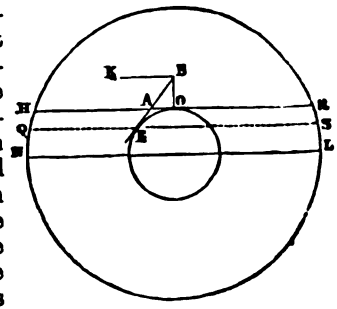


Fig. 11.

The latitude of a place is most readily found by an altitude of the Pole Star. In the annexed figure (Fig. 12), let N be the north pole of the heavens, *n* that of the Earth, Z the zenith of an observer on the Earth at *p*, E Q, *e q* the equinoctial and equator, H R the rational horizon; then, since E N, Z R, are each 90°, if Z N be taken from both, we shall have the remainder N R equal to Z E, or to its equal *p e* (Art. 5), the latitude of *p*; that is, the altitude of the pole equals the latitude of the place. In using the star Polaris, the altitude is taken first when above the pole, and again when below it, and the mean used; or a correction is applied to either altitude, to get the true place of the pole. Again, let *s* be any celestial object, whose declination, E *s*, is known from tables or the *Nautical Almanac;* then, if H *s*, the meridian altitude of *s*, be measured by a quadrant, *s* Z, the complement of this, or difference from 90°, becomes known; now *s* Z and E *s*, make Z E or *p e* the latitude of *p;* that is, to find the latitude of a place, add the zenith distance of a star at that place to the declination of the star. If instead of being south of the zenith and north of the equinoctial, the body be between Z and N, or between E and H, the latitude will be the *difference* between the zenith distance and declination.

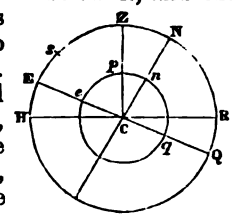


Fig. 12.

It is manifest from this figure, that the difference of the altitudes of the same star at two places on the same meridian, is equal to the difference of the latitudes of the places; for since H R changes its position with the observer, being always 90° from his zenith, Z, and since E *s*, the declination of the star, is invariable, the latitude will depend on the altitude.

If the Sun's altitude is used, and he is not visible when on the meridian, two observations divided by an interval of an hour or two will answer the purpose; but calculation is required. On land, or if the sea horizon is obscured, or the surface disturbed, an image of the celestial object is received on a vessel of quicksilver, on a mirror properly levelled, or other artificial horizon, and the angular distance measured between the object, and an image of it, as far below the false horizon as the object is above; the half of this altitude is then, of course, taken, and to it the corrections are applied.

14. Longitude.—To find the longitude is a problem of much greater difficulty. As already explained, the difference of longitude between two places is the difference of time between them. If, then, an observer could carry Greenwich time with him, and find the time at any place where he might happen to be, he would at once know his longitude. Now, chronometers are constructed of such accuracy as to shew Greenwich time correctly for a long period, when carried to different parts of the Earth; and to find the time at any place, it is sufficient to note with a sextant the instant of the Sun's greatest altitude in his daily path; his vertical diameter is at that instant on the meridian, and the time is noon. The chronometer shews the Greenwich time at that instant; the difference is the longitude west or east, according as time at the place is earlier or later than at Greenwich. If the observer find the G. T. to be 3 P.M. at his noon, then is he in longitude 45° W., as his time is less advanced.

Lunar Method.—But chronometers may go wrong, and they are liable to accident; recourse is therefore had to another method of finding Greenwich time. In the *Nautical Almanac*, published three or four years in advance, are set down the positions of the fixed stars by their declinations and right ascensions, configurations of the planets, eclipses of the Sun, Moon, and Jupiter's satellites, occultation of stars by the Moon, and other celestial phenomena. Among these the distances of the Moon from certain principal or "standard stars," are given for every three hours. These are calculated for the Earth's centre, and set down in Greenwich time. The observer measures with a sextant the Moon's distance from one of these stars, which gives (after correction) the star's position as it would be seen from the Earth's centre; he then finds in the *Nautical Almanac* the time at Greenwich when the star has this same corrected distance from the Moon. He thus knows Greenwich time at any instant; his own time he knows, having taken it at noon by the Sun, and he then gets the difference of time and his longitude.

Jupiter's Satellites.—The use of signals in finding the difference of time between connected stations has been already pointed out. Such a signal seen simultaneously over an entire hemisphere of the Earth, is an eclipse of one of Jupiter's satellites. The times of the occurrence of these are predicted from accurate calculation with the utmost certainty. An observer with the *Nautical Almanac* in his hand, seeing this signal aloft in the heavens, knows the time at that instant at Greenwich; knowing his own time by his mid-day observation, he has his longitude at once. But this method is not easily practised at sea, from the difficulty of managing a telescope on board ship.

Definitions.

15. The sense in which the terms employed in geography are used by us, is given in the following definitions; the advantage of the new term "semi-meridian" will be obvious.

1. The *centre* of the globe is a point within it, so situated that all straight lines drawn from it to the surface of the globe, are equal to one another.

2. The *axis* of the globe is a straight line, which passes through the centre, and on which the globe turns.

3. The *poles* are the points where the axis meets the surface.

4. A *circle of the globe* is a circle described on its surface.

5. Circles of the globe are of two kinds, *great* and *less*.

6. A *great circle* is one which divides the globe into two equal parts, and whose plane therefore passes through the centre.

7. A *less circle* is one which divides the globe into two unequal parts.

8. The *equator* is a great circle, which is everywhere equally distant from the poles.

9. *Meridians* are great circles passing through the poles; and the *semi-meridian* of any point is an arc of the meridian passing through that point, and terminating in the poles.

10. The circumference of every circle is divided into 360 equal parts, called *degrees*.

11. Every degree is divided into 60 equal parts, called *minutes;* and every minute into 60 equal parts, called *seconds*. The mark [°] signifies degrees, the mark [′] minutes, and the mark [″] seconds: thus 23° 27′ 30″ signifies 23 degrees, 27 minutes, and 30 seconds.

A minute of a great circle is sometimes called a *geographical mile*, and sometimes a *nautical mile*. Hence a geographical mile is 1·15 or $1\frac{3}{15}$ statute miles, very nearly.—The mariner's *log line* is divided into equal parts called *knots*, each knot being the same part of a nautical mile that half a minute is of an hour. Hence, the number of knots run out in half a minute will be equal to the number of nautical miles that the ship sails in an hour. The length of one knot should therefore be 50·6 ft.

12. *Latitude*, on the terrestrial globe, is the distance of a point north or south from the equator, measured in degrees on a meridian passing through that point.

13. *Parallels of latitude* are less circles, the planes of which are parallel to the plane of the equator.

14. *Longitude*, on the terrestrial globe, is the distance of a point, east or west, from a given semi-meridian, measured on the equator, or on a parallel of latitude passing through the point.

The semi-meridian, from which longitude is measured by the later British geographers, is that of the Royal Observatory at Greenwich. The semi-meridian of Ferro, the most westerly of the Canary Islands, was long employed by most of the nations of Europe. The semi-meridian of Paris is now used in France,—that of Cadiz, in Spain and Portugal.

15. The *tropics* are two parallels of latitude, drawn one on the north, and the other on the south side of the equator, and each at a distance from it of $23\frac{1}{2}$ degrees of latitude: that on the north side is called the *tropic of Cancer;* that on the south, the *tropic of Capricorn*.

16. The *polar circles* are two parallels of latitude, drawn at the distance of $23\frac{1}{2}$ degrees of a meridian from each of the poles: the northern is called the *arctic circle;* the southern, the *antarctic*.

The space between the two tropics is called the *torrid zone*. The spaces around the poles included within the polar circles, are called the *frigid zones;* those between the polar circles and the tropics the *temperate zones*. The term is applied with some impropriety to the spaces within the polar circles.

17. The *sensible horizon* of any point on the surface of the globe is a plane, which touches the globe in that point.

18. The *rational horizon* of any point on the surface of the globe is a great circle, whose plane is parallel to the sensible horizon of that point.

19. A *continent* is an extensive tract of land, bearing a large proportion to the entire surface of the globe.

20. An *island* is a small portion of land, entirely surrounded by water.

21. An *isthmus* is a narrow neck of land, situated between two pieces of water, and connecting two larger pieces of land together.

22. A *peninsula* is a portion of land, connected to another by an isthmus, and at all other parts surrounded by water.

23. A *promontory* is a piece of land, stretching out into the water, and gradually narrowing.

24. A *cape* is the extremity of a promontory.

25. An *ocean* is an extensive tract of water, bearing a large proportion to the entire surface of the globe.

26. A *lake* is a small portion of water, entirely surrounded by land; or connected to other water only by running streams.

27. A *strait* is a narrow neck of water, situated between two pieces of land, and connecting two larger pieces of water together.

28. A *gulf* is a portion of water, connected to another by a strait, and at all other parts surrounded by land.

29. A *bay* is a piece of water, stretching into the land, and gradually narrowing.

30. When a gulf, a bay, or a salt water lake is very large, it is often called a *sea*. The name *sea* is also frequently given to a portion of the ocean, in some measure enclosed by islands.

31. A *channel* is a piece of water, situated between two pieces of land, too narrow to be accounted a sea, and too wide to be considered a strait.

Origin of the Circles of the Sphere.

16. The great circle marked out on the surface of the heavens by the Sun's apparent annual motion from west to east, is called the *Ecliptic*. Its plane produced to the terrestrial sphere, traces there a circle of the same name.

The two points in the heavens, which seem to be at rest while all the heavenly bodies are moving in parallel circles from east to west in their apparent daily revolution round the Earth, are the *poles* of the heavens. A straight line joining these points and passing through the Earth's centre, is the *axis* of the heavens. The *poles* of the Earth are the points where it meets the Earth's surface. The largest of the parallel circles, which is equidistant from the fixed points, and is therefore a great circle, is called the *equinoctial;* its plane cuts that of the ecliptic at an angle of $23\frac{1}{2}°$, called the *obliquity* of the ecliptic. It is also marked out in the heavens by the Sun in his diurnal motion, on the days of the Equinoxes (March 21, Sep. 21). Its plane produced, forms the *equator* of the Earth. The poles of the heavens are thus the poles of the equinoctial, being points on the surface of the heavens everywhere 90° distant from the circumference of the equinoctial. The poles of the ecliptic are two points on the surface of the sphere everywhere 90° distant from the circumference of this circle. The poles of the ecliptic are thus $23\frac{1}{2}°$ distant from the poles of the heavens. The tropics of Cancer and Capricorn are marked by the Sun in his daily course from east to west, on the days of the Solstices (June 21, Dec. 21). The polar circles are marked out on the surface of the sphere, by the daily motion of the pole of the ecliptic round the pole of the heavens. If an indefinite number of straight lines be conceived to be drawn to the Earth's centre from points in the circumference of each of the tropics and polar circles, the points in which these lines meet the Earth's surface will mark out the tropics and polar circles on the Earth.

The celestial *meridian* of any place is the great circle passing through the pole and the Sun's place, when at his greatest altitude in his daily course, that is, at *mid-day;* the Sun is in the lower part of the circle at *mid-night.* The plane of this circle produced, forms the meridian on the Earth. The intersections of the meridian with the horizon are the *north* and *south* points of the horizon; the intersections of the equator with the horizon are the *east* and *west* points. These four points are called the *cardinal* points; the other points are determined by bisecting each of the four arcs of the horizon between these points, and then bisecting each of the arcs thus found, and so on, there being 32 points in all. The arc between two adjacent points, or the angle at the centre of the horizon measured by this arc, will therefore contain 11° 15′.—The mariner's *compass card* is an horizon divided in this manner, and marked with the various points, hence called the *points of the compass.*

17. Drawing of a Meridian.—The position of the plane of the meridian at any place must be determined before correct astronomical observations can be made, or even a celestial globe used with advantage. There are various ways of doing this.

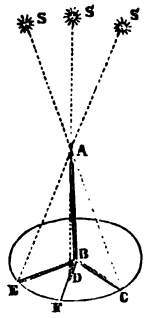


Fig. 13.

a. At the time of either solstice, when the Sun's daily change of declination is least, place a rod or wire, A B (Fig. 13), perpendicularly on a horizontal surface, and an hour or two before noon, mark the extremity, C, of the shadow which it casts. With this length, B C, as radius, and B as centre, describe a circle. Mark also the point D, the extremity of the shadow when shortest, and again after noon the point E, where the lengthening shadow first reaches the circumference. Bisect the arc C E in F, the line joining F and B, which will pass through D if the observations are correctly made, will be in the plane of the meridian; B F may now be produced to any length both ways.

b. The meridian so drawn may be transferred to any other position, by suspending a plummet over the southern extremity A (Fig 14), of the line, and observing when its shadow falls upon the line; the shadow C D, of another plumb line suspended anywhere at C, will at that instant be also in the plane of the meridian; thus the meridian C D is found.

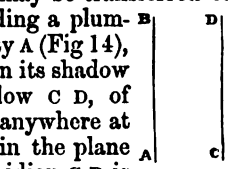


Fig. 14.

c. The following method is useful in setting up sundials:—A chronometer or watch having been previously set accurately to solar time by means of a transit telescope, at a place where the direction of the meridian is of course exactly determined, is carried to the place where the meridian is to be laid down, and gives the instant of noon, and hence the direction of the meridian. If the distance be considerable, the difference of longitude must be allowed for in time. Any other method by which noon is accurately found at the place will equally answer.

d. From the two ends of a rod, A B (Fig. 15), supported on a pivot so as to move freely, suspend two plummets, A C, B D, steadied, if necessary, in vessels of water. Observe when the stars Polaris above the pole, and Alioth in Ursa Major below it, are in the plane of the plumb lines; that plane will then be the plane of the meridian very nearly —the deviation in high northern latitudes being only 7′. The observation may also be made upon Capella below the pole, and Alioth above it, but less conveniently.

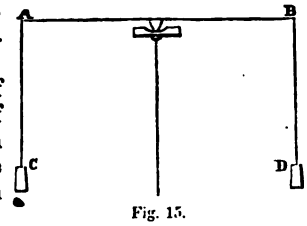


Fig. 15.



THE HIMALAYA MOUNTAINS, THE LOFTIEST ON THE GLOBE.

MAP I.—THE WORLD.

The Land—Its Distribution, Profiles, and Contours—Islands—Diagrams of River Lengths and Mountain Heights.

1. Distribution of the Land.—The unequal distribution of the land on the surface of the globe is strikingly shewn by placing a terrestrial globe so that London may be everywhere 90° from the rational horizon—nearly all the land is then in the upper hemisphere or above the horizon of London; the lower hemisphere contains only Australia, the islands of the Indian archipelago, a small portion of South America, the Antarctic continent, and the Pacific Isles—forming altogether little more than one-twentieth of the masses of land in the opposite hemisphere. If we compare, again, the northern and southern hemispheres, we observe a like striking disproportion; the former contains three times as much land as the latter—the areas being estimated at about 38 and 13½ millions of square miles respectively. South of the parallel of 38° S., we have only the long, narrow promontory of Patagonia, the Antarctic continent, and a few small islands; while in the same latitudes in the north we have a vast extent of land reaching to within 8 or 10 degrees of the Arctic pole. In the southern hemisphere the land between the Antarctic circle and the parallel of 13° S. forms only one-sixteenth of the entire area; while between the Arctic circle and the parallel of 13° N., the land and water are of nearly equal extent. The contrasts of the eastern and western hemispheres, divided from one another by the meridian of 20° W., are no less remarkable; the former contains about 2½ times as much land as the latter, the respective areas being 37 and 14½ millions of square miles. The entire area of dry land is estimated at about 51,250,000 square miles (statute); the area of water at about 145,600,000 square miles; making a total area for the surface of the globe of 196,850,000 square miles. Thus about seven-tenths of the surface are occupied by water, and three-tenths by land. Of the water seven-twelfths are in the southern hemisphere, and five-twelfths in the northern. The distribution of the land throughout the different zones is very nearly expressed by the following numbers, the entire area of the globe being represented by unity:—

Land in the temperate zones, - -	·519
——— torrid zone, - - - -	·398
——— frigid zones, - - - - -	·083

2. Profiles and Development.—The eastern and western continents present striking contrasts, when we compare the directions of the greatest extension of the land. The principal mass of the Old World stretches from east to west over nearly half the

circumference of the globe. In the New World, the land is developed along an axis running nearly north and south, through more than two-thirds of the circumference. On the north both have a comparatively smooth outline, almost coinciding with the 70th parallel; while on the opposite side they run far down into the southern body of waters in great pyramidal prolongations, with extensions beneath the sea, as indicated by islands or banks. South America is continued in the archipelago of Tierra del Fuego; Africa is flanked by a great submarine plateau, called the Lagullas Bank; while Australia has a like extension in Tasmania and its connected islets. In both directions the most prominent points are nearly under the same meridian. Thus, though the principal mass of South America lies to the east of the meridian of 70° W., and that of North America to the west of it, yet it is under this meridian that we find the most northerly and southerly points of the continent, the north-west point of Greenland in 83° N. and Cape Horn in 56° S. The north Cape of Europe, and the Cape of Good Hope are both on the meridian of 20° E.; and Cape Taimura, or the north-east Cape of Siberia, and the extremity of Malaya, on that of 100° E.—Proceeding eastwards from the Atlantic we find three great promontories successively nearer to the pole: Africa terminates in lat. 34°, Australia in lat. 40°, and South America in lat. 56°. The tendency to repeat these pyramidal terminations on their southern sides is seen in Asia, Europe, and North America. Asia presents towards the ocean on its southern side from Behring Strait to Suez, a succession of great peninsulas and promontories, while its outline on the north is almost unbroken by projecting points of land. Europe fronts the Mediterranean with a like series of salient lands and re-entrant bays; and in North America, Greenland, and three large peninsulas taper off in the same manner towards the body of water on the south. The only notable exceptions to this tendency are found in Labrador and Yucatan in America, and Jutland in Europe, all of which are directed northwards. In singular contrast to these broken outlines are the smooth coast profiles of the great southern masses of land, Africa, Australia, and South America. The latter has a compensation in the most magnificent river-system on the surface of the globe, by means of which the continent can be traversed in every direction through almost its entire breadth. The want of such a system, and their unvaried contours seem almost to close up the two former against all influences from without. They have climates of a peculiar character, and civilization and commerce are as yet confined to a few favoured spots along their margins. Europe is placed, in this respect, under more favoured conditions than any other of the continents. Not only is its principal mass characterized by an extraordinary complicity of bay, gulf, and inland sea; but its separate limbs or members thus formed, are again divided in endless variety of prominence and indentation. The facilities thus provided for intercourse among the various races that from time to time have occupied its shores, cannot be regarded as fortuitous—they are obviously parts of a great design for the diffusion of Christianity and the growth of civilization.—The differences of configuration, and the *relative accessibility* of the continents, have been reduced to numerical expression by comparing the areas and extent of sea coast. These are given in the following table, which is calculated for minutes of a degree or geographical miles:—

Continents.	Area in square miles of 60 to 1°.	Length of Coast line.	Square miles to one mile of coast.
Europe,	2,688,000	17,200	156
N. America,	5,472,000	24,000	228
Australia,	2,208,000	7,600	290
S. America,	5,136,000	13,600	376
Asia,	14,128,000	30,800	459
Africa,	8,720,000	14,000	623

The river systems are of course omitted in this estimate; their introduction would greatly modify the *ratios of accessibility*, at least as regards North and South America.

To some less important analogies and contrasts in the horizontal profiles Humboldt long ago called attention, but without professing to have ascertained any "causal connection." Of these we may mention the convexity of Brazil opposite to the deep concavity of the Gulf of Guinea; the convexity of Africa, fronting the deeply indented coast of Central America; the correspondence of the salient and re-entering angles on the west coasts of Africa and South America, and the parallelism of their eastern shores; the opposition of indented and island-fringed coasts to those having an outline smooth and free from islands, and the fiord character of Norway and Scotland repeated in corresponding south latitudes on the west coast of America.



FRAMNAES FIORD, NORWAY.

3. Vertical Contours. — The horizontal profiles, which we have thus briefly sketched, have an intimate dependence upon the vertical contour; that is, upon the direction and height of the mountain ranges, and the situation of the plains. Horizontal extent, and the forms even into which the horizontal outlines are broken, are in most cases determined by the direction of the greatest length of high ground in the interior,—in other words, the *development* of the land is in the same direction as the greater axis of a mountain chain or hill range; and this is true alike of the continents, as of most of the islands, peninsulas, and promontories. The length of America is determined by a vast chain, the longest and most continuously elevated on the surface of the globe. The great breadth of the continent in Brazil, the United States, and Labrador, is obviously connected with the considerable, but much less elevated mountain ranges flanking these plains on the east, and having a general parallelism to one another, and to the shores of the Atlantic.

In the eastern continent a like dependence is observable; the land has its greatest extent nearly from east to west, and this is also the general direction of the principal axes of all its elevated masses; they present undulations much more considerable than those of the New World, but no wide interruption in continuity from the west of Spain to the Sea of Okhotsk and Behring Strait. Here the chains of the two continents are brought into close connection. Together they form a vast girdle encircling the Pacific and Indian Oceans, and surrounding the Mediterranean,—for the Atlas is part of the system. Abrupt towards these oceans, its gradual slopes are directed northwards to the Arctic basin, and in America eastward towards the Atlantic.

The structure of Africa and Australia is essentially different from that of the other continents. They have elevated borders and a comparatively low interior, and are without any single high chain determining the outlines, as in America and Asia. Of Australia we know too little to be able to speak positively, the east border is formed by a high persistent chain; the west by one less elevated and less continuous. The interior between them is comparatively level, and in many parts desert.—Of the Antarctic continent, we only know that it has an ice-bound coast and lofty volcanic peaks in its interior. It has not been, and probably never can be explored.

4. Mean Height of Land.—Mountain chains and table-lands influence in the most remarkable way all terrestrial phenomena, and to some extent the political and social relations of all the adjoining nations. Yet is their mass insignificant in comparison to the low and level tracts. To reduce this to numerical expression, Humboldt made approximate estimates of the quantity of matter in chains and plateaux, calculating that of the former as triangular prisms, that of the latter as parallelopipeds, with due allowance for irregularities of outline, and departure from these exact figures. Thus, taking the area of the base of the Pyrenees at 1720 square miles (statute), and the mean height of the 48 passes over the crest (excluding the two roads at the end of the chain) at 7990 feet, the quantity of matter in the chain is such as, if spread equally over Europe, would raise its surface 6 feet, and if spread over France, would raise it 115 feet. The Alps cover a base four times greater than that of the Pyrenees, but the passes have a mean height 300 feet less. The matter distributed, would raise the mean level of Europe 22 feet; that of the Spanish plateau, whose mean height is 1920 feet, would raise Europe 36 feet. The plateau of Tibet, with its great bounding chains, would raise Asia 358 feet. Taking in this way the means between all the high lands and all the low lands, the mean elevations of the continents have been found approximately as follows:—Europe, 671 feet; North America, 784; South America, 1132; Asia, 1152. The mean elevation of Asia is so small, notwithstanding its vast chains and table-lands, on account of the great extent of the Siberian plains, and the *depression* about the Caspian, which form together one-third of the continent, and have a mean elevation of no more than 255 feet. This fact, in connection with the slight elevation of North Europe and North America, places in a striking light the low level of the Arctic regions. The mean height of all the land on the globe is estimated at 1000 feet: of the New World, at 930 feet; and of the Old, at 1010.

5. Islands.—The islands of the globe have been estimated to contain about one-twenty-third of the area of all the continents. They are divided into two groups, the continental and pelagic. The former are those which are closely connected with continents, like the adjoining mainland in physical aspect, in their fauna and flora; the latter, those dotting the surface of the ocean far away from land. Taking their features from an axial chain parallel to, or in continuation of one upon the mainland, continental islands are generally much extended in one particular direction; while pelagic isles are either without mountains, or receive their form and outline from a central peak or group. Pelagic isles occur in countless multitudes over the surface of the central and western Pacific, and there are a few in the Atlantic, Indian, and Southern Oceans. With a very few exceptions, these are all either of volcanic or coralline formation, or have been produced by the joint action of volcanic forces and the coral-building polypi. The few exceptions to this rule are the Seychelles in the North Indian Ocean, which consist chiefly of granite and quartz rock, Kerguelen's Land in the southern part of the same ocean, having an axis of primary rocks, with a volcanic group in the north, and New Caledonia, 1000 miles north of New Zealand, which has a central ridge of old rocks, and fringing reefs of coral.

6. Rivers.—The declivities of the land determine the fall of rivers, the direction being usually at right angles to the axis of the ranges, which send them off, and in most cases the size of the river depends on the length of its course; usually also, the countries with a great rainfall are those in which the largest rivers are found. The Shannon in Ireland is an exception to the first, there being perhaps no river with so short a course and so great a

body of water, while it is otherwise exceptional as running parallel to the sea coast, and at no great distance from it, instead of issuing from the centre of the country. The Nile is a striking exception —its course being certainly the longest in the world, but the body of water by no means comparable to that of many shorter streams. In or near the tropical regions, the larger rivers ought to be found, as the rain-fall is greatest; and we find it thus in South America, where the Amazons, the largest of the globe, is also the only one whose course is almost wholly along the equator. The Missouri-Mississippi is indeed no doubt longer, but its discharge is less. The two greatest rivers of the world, then, are on the American continent, and they form a pair almost exactly equal in all their main features—both are navigable through nearly 2000 miles. Comparable to the two great streams of America, are the two great rivers of Asia—the Yang-tse and the Whang-ho, which have their sources in the ice caves of the vast central plateau, have immense volumes of water, and are navigable without hindrance through nearly 2000 miles. One river of Asia, the Burrampooter, presents the marvellous anomaly of having the principal part of its course at the height of 11 to 13 thousand feet above the sea, and being here navigated for many hundreds of miles. But an account of the other streams would lead into long details, for which there is no space; it must suffice here to refer to the scheme upon the map.

7. Mountains.—The diagram in the map brings the principal mountains of the continents into close comparison, and an examination of it will serve the purpose of a detailed description. As the various chains fall more naturally to be described under the accounts of the physical structure of the various continents, it will be unnecessary to do more here than refer the reader to the scheme. Asia, in its Indian Himalaya, has the loftiest mountain, Deodhunga or Gaurisankar; and in a circuit of two or three hundred miles from it on this and the connected chains, there is a greater number of lofty peaks than in any other part of the world—a vast assemblage, the height of all of which much passes the heights even of the loftiest Andes, which come next to these giant peaks of Asia. Wondrous, impressive, awe-inspiring as they are, and fitted to raise the soul in adoration of the power and majesty of the Creator, yet are they withal less picturesque and pleasing than lesser chains, amid which we have the added charm of winding lake, rugged crag, embosomed isle, and hanging wood.



GENERAL PHYSICAL ASPECT OF EUROPE.

MAP II.—PHYSICAL MAP OF EUROPE.

8. This continent presents in its form and outlines a most remarkable contrast to all the other continents on the surface of the globe. The compact body of non-peninsulated dry land is very small compared to that contained in any other continent, so deeply intersected is it on all sides by gulfs and bays. This is at once made apparent by laying off upon a map an elliptic area from the northern point of

Moravia as a centre, with the semi-axis major reaching to the mouth of the Danube, while the semi-axis minor reaches the head of the Adriatic.—Access to the heart of the continent is thus had on all sides; and this structure, in connection with the great number of large navigable rivers, has contributed immensely to the intercourse of its people and the development of its resources. Though but one-third the size of Africa, the coast line of the inland seas, estuaries, and oceanic boundaries, makes a greater total water-boundary than that of this continent (Art. 19).

These peculiar features of Europe are intimately related to the disposition of the masses of high land on the continent. A broad and nearly continuous zone of mountains traverses it in a direction which is approximately from east to west, or nearly perpendicular to the Atlantic coast, while on either side of this the surface is so low and level, that oceanic influences are freely admitted even to the central elliptic area most remote from any body of water. The two great inland seas opening off the Atlantic, and the great Northern plain, give ready access for the prevailing westerly currents of the atmosphere, charged with a load of moisture, to the interior of the continent. Hence arises the mild climate which most of the countries enjoy, even in the highest latitudes, and which stands in singular contrast to the character of the seasons in the same latitudes in the New World. If the direction of the elevated framework of high land had been meridional and near the west coast, and its elevation even no greater than we find it, the interior of the continent would have been very differently circumstanced as regards moisture and general temperature; and such an *excessive* climate might have reigned over very large portions of it as now prevails in the middle and eastern parts of Russia. Such a chain would have arrested the warm moist currents, and obliged them to deposit nearly all their load against the cool summits, as mountain ranges not so high do in other countries—notably India and Ceylon. The range itself would have been well watered, and would have been a storehouse for a persistent supply of perennial streams, parting off on both sides; but the central and eastern plains would have received from these winds but a scanty supply of moisture; and instead of latent heat being set free, caloric would have been absorbed and evaporation promoted. Over Central and East Russia, some such effect as this is really produced, even under the actual configuration of the surface of Europe. Before reaching so far, the westerly currents, which are the great source of moisture and mild climate in Europe, have lost to the mountain ranges, across which they must pass, nearly all their moisture—they are dry and cool, and promote evaporation. Besides, the country is completely open to the north and north-east, so that Arctic influences rule supreme. But had the Ural been an abrupt chain of somewhat greater altitude and transverse to the meridian, the climate of the east of Europe would have been very different. Remarkably contrasted with it is the climate of the north-western part of the continent, which enjoys much milder seasons in latitudes considerably to the north. Here, and along the western coasts generally, the waters of the Gulf Stream exercise a powerful influence over and above those effects which are due to the proximity of the ocean. The tepid waters warm the air, and milder temperatures are diffused than would otherwise prevail. It is also important to remark, that Europe lies wholly within the region of variable winds, and thus becomes liable to many local influences not found on the other continents, which greatly modify the character of her climate.

9. Climates.—With certain local exceptions, the following division of Europe into zones will convey a correct notion of the climates:—

1. The sub-tropical zone, embracing the south of Portugal, as much of Spain as is bounded north by a line joining Cape St. Vincent to Cape St. Martin and the Balearic Isles, the southern half of Sicily, and the southern promontories of Italy. Sheltered by the high lands on the north, and open to the sea influences and to the warm winds of Africa, this zone forms one of the most delightful regions of Europe, and nourishes many vegetable forms found nowhere else on the continent, and usually confined to the tropics or their borders. It is also the only abode in Europe of a quadrumanous animal.

2. The southern zone, reaching from lat. 38° to 45° N., and embracing Spain, the south of France, Italy, Greece, and the south of Turkey. Here the summer temperature reaches 100° F.; winter is short, little snow falls, and spring is early. The weather is generally dry, with cloudless skies; the average rain-fall about 37 inches; number of rainy days 90 to 100. Local exceptions occur in Spain on the plateau of Castile, which, owing to its general elevation and the proximity of snow-clad mountains, has a temperature in winter much lower than is due to the latitude; and also in the mountain tracts in the north of Greece.

3. The middle zone, from lat. 45° to 55° N., embracing the central and northern parts of France, the Netherlands, Germany, and the southern parts of Russia. The summer temperature reaches 90° generally, except in the east of Europe, where it often attains 100° to 110° F. The snow-fall is considerable; winter is the longest season, autumn the shortest; rain-fall about 26 inches, except under peculiar local conditions; the number of days on which rain falls is on an average from 150 to 160. The most remarkable exception is South Russia; here the climate is excessive, from a cause already explained; snow lies for four or five months, the skies are clear as in Canada, and the cold very severe; the spring lasts for but two or three weeks, and vegetation rushes rapidly into summer luxuriance. On the west coast of France, in the same latitude, snow is almost unknown.

4. The northern zone, from lat. 55° to 70° N., embraces all the north of Europe, in which the contrasts are very great, especially towards the north, where the Sun does not set for months, and the heat is not dissipated by the occurrence of night; and for a like reason, the cold of winter is not moderated at the opposite season; the rain-fall, with

local exceptions, is no more than 16 or 18 inches; rainy days, 150 to 200. In this zone, as in the third, the contrasts between the summer and winter temperatures increase greatly as we advance towards the east, giving to this part of the continent the like excessive climate which prevails on the eastern sides of North America and Asia.

10. The Mountain Zone.—The broad belt of high land which impresses its marked physical character on the European continent, is but the western portion of an immense zone of mountains which girdles the central part of the Old World from Cape St. Vincent to Behring's Strait, where it comes into close connection with the great dominant chain of the New World; while at the south-west extremity it is separated from the north-western range of the Atlas only by the narrow interval of Gibraltar Strait. The eastern and western sections of this great zone almost coalesce on the boundaries of the two continents, being separated only by the narrow depression occupied by the Dardanelles, the Sea of Marmora, and the Bosphorus. The western section may be conveniently divided into six systems—the term *system* being understood to mean a set of mountain groups dependent upon a main or axial range, or closely connected with one another in structure and direction, though no mineral axis should exist among them. The term, however, is often applied very loosely by geographers; it is rather a misuse of terms to designate a single range or chain like the Caucasus or the Ural by the name of a system, which in strictness is applicable in Europe to the Alps only. Taking then the term in its looser sense, we may arrange the European mountains into the six following systems:—The Iberian, Alpine, Carpathian, Caucasian, Uralian, and Scandinavian.

11. Iberian Mountains.—The mountains of the Peninsula have a certain mutual connection, yet scarcely such as to entitle them to the name of a system in a strict sense. The Pyrenees, the principal chain, are, however, by means of other chains inosculating with them, joined indirectly with all the ranges of the Peninsula, except, perhaps, the Sierra Nevada. The Pyrenees separate France from Spain, and with their lateral branches extend a considerable way into both countries. The length between the Mediterranean and the Atlantic is about 270 miles, and the breadth about 90 miles; culminating point Maladetta or Mauduit (lat. 42° 30′ N., lon. 0° 30′ E.), 11,424 ft. high. The numerous lofty branch chains on both sides are separated by fine Alpine valleys, which communicate by passes across these off-sets. The axis of the chain is granite, usually flanked by primary schists, but overtopping them, and thus forming the loftiest summits. Mount Perdu, 11,168 feet high, and Marbore, 10,050 ft., are the chief exceptions; their upper parts consist of fossiliferous limestone, most probably of the chalk formation. The minerals of the chain are unimportant; but mineral springs, both cold and thermal, are very numerous. The latter issue at the junction of the granite with the slate rocks, as if the granite, once melted, was not yet cold at great depths! There are magnificent forests of deciduous trees, which afford much finer contrasts of colour than the sombre fir-woods of the Alps. The chain of the Pyrenees has two remarkable features: it consists of a single ridge with a narrow and almost unbroken crest, like a huge rampart reared up between the two seas; and it is without longitudinal valleys. The crest is notched by about 50 passes, expressively called *portes*, from their resemblance to doors cut in the rock, and rarely more than 1000 ft. lower than the summits of the mountains. They are impracticable for wheel-carriages, and the only roads of this kind are two, one at each end of the chain—the Col de Pertus on the Mediterranean shore, and the pass of Bidassoa on the Biscayan coast, where the chain declines somewhat before plunging into the sea. The most remarkable passes are the "Breche de Roland," and the "Porte de Venasque," which affords a magnificent view of Maladetta. The highest summits are not on the crest proper, or main axis, but on spurs passing off to either side. The narrowness of the crest, and the existence of lateral valleys only, imply the absence of large snow-fields and glaciers comparable to those of the Alps, and of lakes of any considerable magnitude. The granite of the Pyrenees is considered to be newer in most parts than the cretaceous rocks, in some places perhaps even than the lower tertiary; and it is probable that the whole chain was elevated suddenly towards the close of the chalk period.

That part of the chain which terminates on the sea coast near the mouth of the Bidassoa, is not on the axis proper of the Pyrenees, but is a branch chain, given off at the head of the valley of Bastan near the "gloomy Roncesvalles Strait." The main axis bending here slightly into a direction due W., traverses the northern part of Spain 20 to 35 miles from the coast, as far as lon. 6° W., where it divides into three branches terminating at Capes Ortegal, Finisterre, and Selleiro. This is the Cantabrian chain of Malte-Brun, designated locally by various names in its several parts, one of which is the Sierra Alba, W. of Reynosa, the principal heights of which range from 5700 to 6900 ft.; culminating point of the whole chain, Peña de Peñaranda 10,910 ft., 35 S.S.W. of Oviedo, on a south spur. Near Reynosa, between the head waters of the Ebro and Douro, the Sierra Alba is connected with a long line of high ground, in some places rising into mountains, which extends continuously S.E., S., and S.S.W. to Cape St. Martin in Valencia, with a branch to Cape Palos in Murcia. With the Pyrenees it forms the basin of the Ebro (*Iberus*), which it divides from the basins of all the other Spanish rivers, whose head waters lie along it, and whose course is nearly at right angles to that of the Ebro; the culminating point of this series of chains and plateaux—for it can scarcely be called a chain—is Monte Moncayo in the Sierra Deza, 27 miles E. by S. of Soria, 9600 ft. high. With this high watershed, the other ranges of the Peninsula, traversing the country in a direction between W. and S.W., form a series of mountain knots. These are the Castilian mountains and Sierra d' Estrella, terminating in Cape Roca, highest point, 35 miles S.W. of Avila, 10,531 ft.; the Sierra de Toledo, ending at Cape Espichel, near Setuval,

highest point 5115 ft.; the Sierra Morena, ending at Cape St. Vincent, highest point 5500 ft., 38 miles S.W. of Llerena; and the Sierra Nevada, terminating at Cape Trafalgar, culminating points Mulhacen and Veleta, N. of Motril, 11,678 ft., and 11,387 ft. Gibraltar Rock (Djebel-el-Tarek, Tarek's Rock, named from the first Moorish invader) is an outlier of this range, height 1451 ft.

These various chains send offsets into the valleys on either side, and most of them have minor parallel ranges and table-lands placed as buttresses to the main chain. South-west offsets from the Pyrenees traverse Catalonia, and in the north of Valencia approach the high watershed already noticed, thus forming a second southern connection with the Pyrenees.



GIBRALTAR ROCK.

12. Gallic Chains.—Closely connected with northern offsets of the Pyrenees, which reach to the valley of the Aude and canal of Languedoc, a high chain has its origin near Carcassonne and Castelnaudary, and runs continuously N. 400 miles, chiefly under the name of the Cevennes (Cebenna of the Romans) and Monts d'Or, to the sources of the Seine, Meuse, and Saone; thence bending N.E., it assumes the character of an irregular plateau, to become a mountain chain again in the Vosges of the Palatinate (Wasgau of the Germans) and the Taunus of Nassau, whose declining heights bring it almost into connection with the Harz forest and the Teutoburger, which drop down into the great plain of North Germany. The greatest altitudes of this chain are found in the south about the sources of the Loire and Allier, where they reach nearly 6000 ft., though a single summit near Clamecy (dep. of Nievre) is somewhat higher; the Vosges present none of quite 5000 ft., and northwards the heights are little over 2000 ft. From this great watershed of Eastern France, three continuous ranges pass off westward, dividing the rich plains of the three great rivers almost to the Atlantic; one terminates near Nantes, another at Brest, while the Argonne and the Ardennes reach from the sources of the Meuse and Saone to the Strait of Dover. This latter, on the borders of France and Belgium, does not much pass 2000 ft.; the middle chain declines from nearly 3000 ft. to 1300 ft. near Brest; the central chain in M. Dor, in Auvergne, and Oulouze near Limoges, reaches heights from 6200 to 4500 ft.

Alpine System.

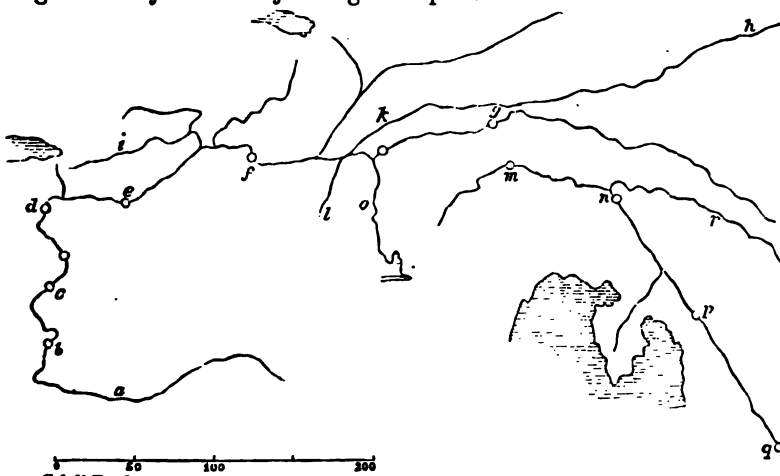
13.—Separated from this great range and its offsets by the valleys of the Saone and Rhine, the Jura and its continuations northwards into Germany, the Schwartzwald and Odenwald, are properly parts of the Alpine system. The centre of this, the only true mountain system of Europe, is near the middle of Switzerland, in the south part of the canton of Uri, where those of Berne, Vallais, Tessin, and Grisons border with it. Here, within a radius of 6 to 8 miles, there lies a mass of very lofty mountains, called the St. Gothard group, from which six great valleys, each containing a river, and five great mountain chains, radiate in all directions. The valleys are those of the Rhone, Aar, Reuss, Fore-Rhine, Ticino, and Toccia. The mountain chains are—the main chain of the Alps, towards Mont Blanc; the Bernese Alps, separating the basins of the Rhone and Aar; two chains running N.W. and N.E., dividing respectively the courses of the Aar and Reuss, and those of the Reuss and Fore-Rhine; and, lastly, the great main axis of the Alps, running E. between the Rhine and its affluents on one side, and the tributaries of the Po on the other. All these natural features are well seen upon a good map of Switzerland. But as the Alps stretch into the adjoining countries, it will be more convenient to begin at the most southerly limit, and then to pass continuously along the chain, following the course of the central axis, and the chief branches proceeding from it.

This central axis from the E. frontier of France to the W. frontier of Hungary, consists of a broad band of igneous and other crystalline rocks, on either side of which the newer formations are symmetrically developed on a scale of magnificence corresponding to the magnitude of the mountain masses which lie along the axis. It is, however, a peculiar feature in this structure, that the palæozoic rocks are almost entirely absent—wholly from the western and central Alps,—while there is a vast development of those of newer age upwards from the Trias to the most recent tertiaries, both inclusive. So complete and wide-spread is the metamorphism, that the sedimentary deposits at long distances from the axis assume the aspect of crystalline schists, and can only be identified by their fossils. The Eastern Tyrol, on the S. side of the axis, is remark-

able for a wondrous assemblage of mountains of dolomitic limestone, whose singular positions and forms have led some geologists to suppose that they were built up as coral-reefs in an ocean, the floor of which slowly sank to an enormous depth. There are two systems of valleys in the central and eastern Alps —the longitudinal in the line of the axis, and the transverse at right angles to it. The groups S.W. of M. Blanc have not this structure—they resemble the Pyrenees in having transverse valleys only.

The most convenient southern limit of the Alps is the Col di Tenda, N. of San Remo, in the province of Nice, a pass from the coast into the Lombard plains. East of it the mountains are lower than on the west side, and are called Apennines by the natives. The Col di Tenda is in lat. 44° 10′ N., lon. 7° 40′ E., and is 5890 ft. high; across it the great road leading from San Remo to Coni in Piedmont passes—the only road practicable for wheel-carriages W. of the Bochetta Pass, which is N. of Genoa, and only 2550 ft. high.

Central Chain.—Beginning at the Col di Tenda and proceeding W., N., and E., we have the following subdivisions of the Alpine system, which, with their designations, are nearly the same as those established by the Romans: they are represented in a general way on the adjoined ground-plan.



a, Col di Tenda.
b, Monte Viso.
c, Mont Thabor.
d, Col du Bonhomme.
e, Monte Rosa.
f, Vogelsberg.
g, Drei-herrn-spitz.
h, The Wienerberg, near Vienna.
i, Bernese Alps.
k, Vorarlberg chain.
l, Bernina.
m, Drei-Schuster peak.
n, Mount Terglou.
o, Ortler-spitz.
p, Mount Kleck.
q, Mount Dinara.
r, Reka mountains.

1. The *Maritime* or *Ligurian Alps* (*a b*) extend from the Col di Tenda to Monte Viso, 65 miles. Spurs stretch S. and S.W. to the sea-shore, forming, with their valleys, terraces, and slopes, the rich and picturesque region called the Riviera. The principal heights are, Col de Longet, 9345 ft., the Mont Clapier, 10,433 ft., Rioburent, 11,142 ft., Aiguille de Chambeyron, 11,155 ft.

2. The *Cottian Alps* (*b c*) extend N.W. and N.E. from M. Viso to M. Thabor (*c*) 45 miles; so named from Cottus, king of the country in the time of Augustus. Principal heights—M. Viso, 12,643 ft., Levanna, 12,020 ft., Roche Melon, 11,606 ft., M. Thabor, 10,436 ft., M. Genèvre pass, 6160 ft., from France by Susa to Turin. In Dauphiné, on a great offset, are the Pointe des Ecrins, 13,462 ft., and M. Pelvoux, 12,973 ft.

3. The *Graian Alps* (*c d*) from M. Cenis pass to Col du Bonhomme (*d*) W. of M. Blanc, 55 miles. The origin of the name is unknown. Principal heights — Grand Paradis 13,300 ft., Aiguille de la Sassiere 12,346 ft., M. Pourri, 12,800 ft., the Grivola 13,005 ft., pass of M. Cenis 6775 ft., of the Little St. Bernard W. of M. Blanc, 7192 ft. By one of these Hannibal most probably crossed B.C. 218.

4. The *Pennine Alps* stretch from Col du Bonhomme to M. Rosa (*e*) due E. 60 miles. The name is derived from the Celtic word *Pen*, a great mountain, *Ben* in Scotland and Ireland, *Pen* in England and Wales. Height of M. Blanc 15,810 ft., M. Rosa 15,217 ft., Matterhorn 14,705 ft., the Dom, on a N. spur, 14,935 ft., the highest in Switzerland; Weisshorn 14,804 ft., and 8 others not less than 11,000 ft.; pass of the Great St. Bernard, from Martigny to Aosta, 8150 ft. at the hospice —crossed by Napoleon, May, 1800, with 30,000 men.

5. The *Helvetic* or *Lepontine Alps* (*e f*) extend in a great arch N.E. and S.E. 85 miles, from M. Rosa to the Vogelsberg and pass of Bernhardin at the source of the Hinter-Rhine, the greatest convexity of the arch being at the St. Gothard group already noticed. The names are taken from those of ancient tribes. M. Leon 11,541 ft., Galenstock 11,956 ft., Pizzo Rotondo 10,500 ft., Pizzo Pesciora (whence streams flow into three seas) 10,300 ft., Vogelsberg 10,870 ft.; Furka Pass 8000 ft., pass of the Simplon, from Brieg to Domo D'Ossola, 6578 ft., of the Bernhardin 7115 ft.

6. The *Rhaetic Alps* (*f g*) extend E. by the source and right bank of the Inn to Drei-herrn-spitz in Tyrol, 160 miles. The name is taken from that of an ancient people. Piz Morteratsch 12,316 ft., Ortler-spitz, on a S. offset range, 12,852 ft., Piz Roseg 12,936 ft., M. Disgrazia 12,060 ft., Piz Bernina 13,294 ft., Drei-herrn-spitz 10,122 ft.; pass of the Splügen, between the Hinter-Rhine and the Adda, 6814 ft., pass of the Stelvio road constructed in 1824, connecting the valleys of the Adda and Adige across the lofty neck of land joining the Ortler-spitz to the main range, and so opening a way N. into Tyrol, 9174 ft., being the highest carriage road in Europe. West of this, near the Maloya Pass, is the village of Soglio, the highest in Europe, height 6714 ft.

7. The *Noric Alps* (*g h*) extend N.E. 200 miles from Drei-herrn-spitz towards Vienna—name from an ancient tribe and Roman province. From about 20 miles E. of the Gross Glockner, the chain begins to decline in height; yet at Neustadt, 30 miles S.E. of Vienna, is still 6950 ft. high in the Schneeberg. Eastwards the chain branches out, one branch ending in the Wienerberg near Vienna, the other uniting with the Bakony mountains N.W. of the Balaton Tava, both branches thus approaching the Car-

pathians, which here press close on the Danube. Gross Glockner 12,776 ft., Ober Wiesbachhorn 11,518 ft., pass of Semmering, 30 m. N.E. of Bruck, 3325 ft., highest of Bakony range 2378 ft.

14. Offset Chains.—1. The *Bernese Alps* reach from the Galenstock, dominating the Rhone glacier, to Dent de Morcles W. of Martigny, 80 miles. This chain rivals the Pennine in the stupendous height and imposing forms of its majestic mountains. The glaciers and snow-fields encircling and isolating its lofty peaks unite on all sides, and form perhaps the most magnificent ice-field on the globe. At St. Maurice near Martigny, a gorge between Dent de Morcles and Dent du Midi, the width of the Rhone and the road, divides this chain from an offset of the Pennine running from M. Blanc towards Lake Leman. Finster-aar-horn 14,026 ft., Jungfrau 13,718 ft., Mönch 13,498 ft., Eiger 13,075 ft., Schreckhorn 13,386 ft., Viescherhorn 13,321 ft., Wetterhorn 12,210 ft., and 7 others above 11,000 ft.; the Brevent over Chamouni 8270 ft., Dent du Midi 10,449 ft., Dent de Morcles 9757 ft.; pass of the Gemmi 7560 ft., of the Grimsel 7200 ft.

2. The *Brünig* and *Titlis* ranges run from the N. side of the St. Gothard group W. and N. towards Soleure, Lake Lucerne, and lake of Zurich. The Dödi and Scheibe ranges, on opposite sides of the river Linth, diverge from the same centre towards the Linth canal and Lake Wallenstadt; the latter is continued through Appenzell and St. Gall towards the lake of Constance. 3. From the Maloya Pass, a long chain stretches to the N.E. and E. on the left bank of the Inn, spreading out into the so-called *Bavarian Alps*. The Vorarlberg range diverges towards the S.E. angle of the lake of Constance, dividing the basins of the Lech and Ill. The Alps of Algau, a branch of this latter, almost establish a junction with the plateau of Würtemberg, of which the Rauhe Alp is the eastern border. Principal heights, Süstenhorn 11,627 ft., Titlis 10,620 ft., Uri-Rothstock 10,106 ft., M. Pilatus 7080 ft., Dödi 11,766 ft., Scheibe, in S.E. of Glarus, 9986 ft., Rigi 5676 ft., Sentis (S.W. Appenzell) 8268 ft., Arlberg 10,200 ft., Solstein, N. of Innsbruck, 9702 ft., Watzmann, near Königsee, 9654 ft.

4. The *Carnic Alps* (*m n*) form an arch round the head of the Gulf of Venice, the apex being near the Drei-Schuster peak, dominating the upper Gailthal. Marmolata 11,749 ft., Cimon della Pala 11,100 ft., Drei-Schuster 10,375 ft.

5. *Julian Alps.*—These form a lofty group connecting the last with M. Terglou, S. of which a long and high limestone plateau breaks the continuity; beyond this the mountain ridge, again resumed, has received the same designation; but Mr Ball (Eastern Alps, chap. xvii.) limits the name to the group near the Terglou. Towards Gradiska branches of this range come close to the Balkan. M. Terglou 9371 ft., Schneeberg, 40 m. E. of Trieste, 7457 ft., M. Kleck 6926 ft.

6. The *Dinaric Alps* (*p q*) stretch S.E. from M. Kleck in the Kapella range, and unite with the range of Pindus or Grammos in Turkey, taking the name from M. Dinara E. of Zara. They unite also eastwards with offsets of the Balkan, which form high plateaux with hill ranges near Yeni-bazaar and Pristina, themselves united to Pindus on the W., and on the S.E. to Rhodope or Despoto, an offset from the Balkan near Sophia. The Pindus range runs into that of Othrys and N. Greece, which is continued in two branches, one ending in Cape Colonna, "Sunium's marbled steep," the other at the S. end of Micone, having traversed Eubœa, Andros, and Tinos. M. Dinara (*q*) 7458 ft., M. Plissivitza (45° N.), 5742 ft.; highest of Balkan, M. Scardus, near Yeni-bazaar, 9700 ft., average height E. of this 3000 to 5500 ft.; highest point of Rhodope 7800 ft.; of M. Olympus, Thessaly, 9754 ft.; of Pindus 9000 ft.; of Greece, M. Guiona, near Salona, 8240 ft.; of the Morea, M. St. Elias (Taygetus), near Sparta, 7829 ft.

7. The *Reka* or *Kara-wanken Alps* (*r*) stretch from M. Terglou E., and then S.E. between the rivers Save and Drave, declining to 4000, 3000, and 2000 feet in height.

8. The *Apennines* extend from the Col di Tenda E., and then S.E. through the middle of Italy, and, interrupted only by the narrow Strait of Messina, are continued under the name of the Madonian Mountains due W. through Sicily. Vesuvius and Etna are volcanic excrescences quite cut off from these chains. Mean height 4300 ft.; many summits 6000 to 9000 ft.; highest point M. Corno or Gran Sasso, N.E. of Aquila, 9544 ft., Madonian 7000 to 9000 ft., Etna 10,874 ft., Vesuvius 3600 ft.—all under the line of perpetual snow.

9. The *Corso-Sardinian* chain has a manifest dependence on the maritime part of the Alpine system, and is a high rugged ridge rising in M. Rotondo, d'Oro, and Capella, in Corsica, to 8764 ft., 8698 ft., and 6750 ft. respectively, and in Sardinia to 5276 ft. The highest points nourish perpetual snow, though lower than the Apennines, owing no doubt to the more moist climate.

15. The **Carpathians** encircle Hungary and Transylvania, and send off low ridges towards the Balkan at the Iron-gate, where the Danube forms a wild gorge in the hills. They are in most parts a single chain with few longitudinal valleys, and consist chiefly of separate groups connected by high plateaux; the highest points range from 9912 (Ruska Poyana) to 8700 ft. (Bucsecs, near Kronstadt): none of the summits have perpetual snow. They unite N.W. with the Sudetic mountains or Riesengebirge, which, with the almost continuous ranges of the Böhmerwald and the Erzgebirge, surround Bohemia on three sides; the two latter at their point of union form a connection with the Fichtel-gebirge, whence ridges of high land extend S.W. towards Würtemberg, and N.W. to the Thuringerwald, which stretch towards the Harz (an isolated mass) and the Teutoburger of N.W. Germany.

16. The **Ural** and the **Scandinavian** ranges are entirely independent of the other mountain systems of the continent.

The Ural extends N. and S. from the Orenburg Steppe to the Arctic Ocean through 1300 miles, or 20° of latitude. They have moderate slopes on the European side, and steep escarpments towards Siberia: mean height 2000 to 2500 ft.; highest point

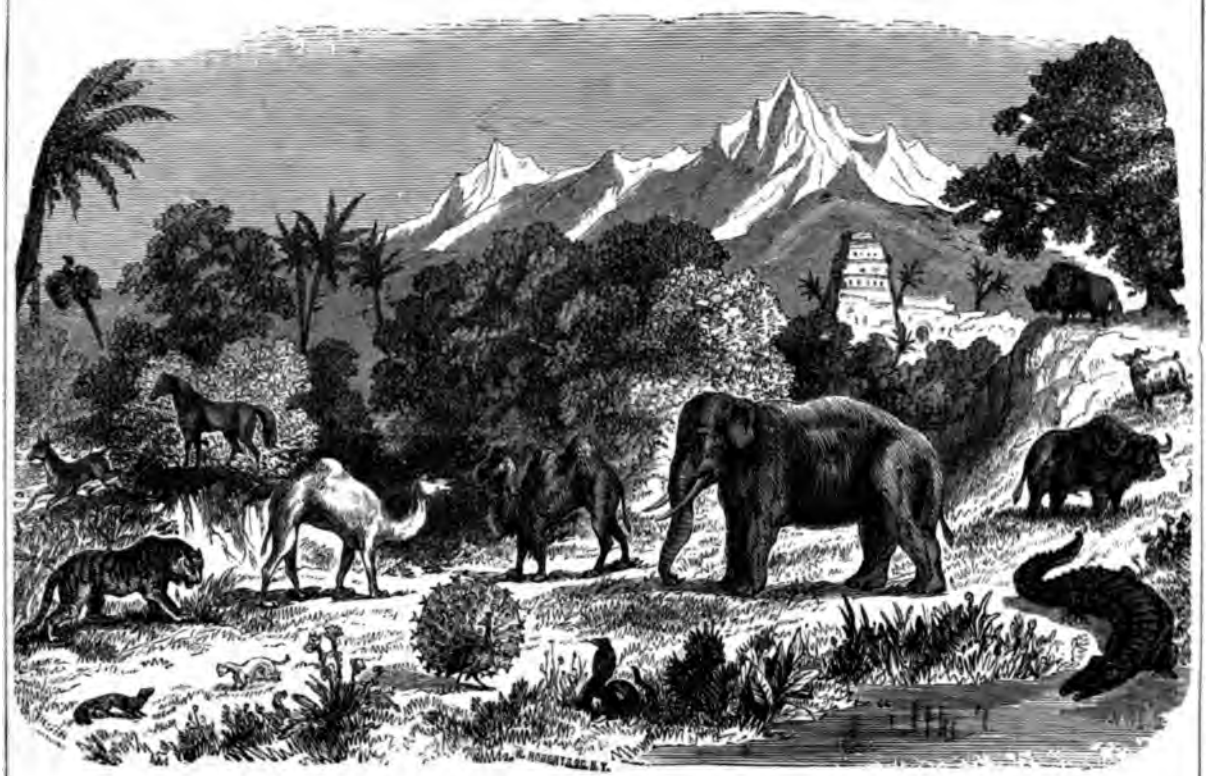
(lat. 59° 30′) 5720 ft. The Timan is sent off N.W. in lat. 62° towards the Arctic Ocean, height 1000 ft.; and in lat. 65° the Obdorsk mountains N.E., greatest height 5286 ft. The chain is rich in metals, chiefly gold, and its vast forests are a source of great wealth.

17. The Highlands of Scandinavia, from Cape Naze to lat. 61°, part of which go by the name of Dovrefeld, consist of vast plateaux of the average height of 4000 ft., and are very level through long distances. They have no distinct watershed, but are intersected almost to their centre by long deep narrow valleys proceeding from either side, and the heads interlacing, so that a zig-zag course must be held along them to avoid the gullies. Isolated peaks, 2000 ft. to 4000 ft. high, are set down on these barren table-lands; highest point Store-Galdhöpiggen, in the Ymes-fjeld, N. of Sogne fiord, 8400 ft. From lat. 61° northwards, there is a fine mountain range called the Kjolen, with parallel ridges and spurs, which culminates in Sulitelma (lat. 67½°), 6200 ft. high; towards the N. Cape it sinks to near 2000 ft. Seaward and along the sides of the vast fiords, the coast ranges and spurs terminate in tremendous mural precipices, over which waterfalls discharge themselves; and there depend in many places the ends of great glaciers, fed by the vast snow-fields which overspread the higher peaks and plateaux.

18. Plains.—The great plain of N. Europe, called the German and Sarmatian plain, extends from Dover Strait through the Netherlands, N. Germany, Denmark, the Baltic provinces of Prussia, and expands widely eastward so as to embrace Poland and European Russia from the White Sea to the Euxine, where, passing round the S.E. flanks of the Carpathians, it becomes confluent at the delta of the Danube with the plain of the Principalities. Cutting off the Ural from the plateau of Ust Urt, between the Aral and Caspian Seas, it sweeps round E. and N., and comprehends much of Western Siberia. Throughout its entire western part, there is no greater height than 500 ft., and no rock *in situ;* vast transported rock-masses are found along the Baltic shores, spread over the surface of the sandy moorlands, which must have travelled from Scandinavia when the Baltic was filled with ice; but in Russia the Valdai hills vary the level in a low boss only 900 ft. high, across which, with a rise almost imperceptible, the railway from St. Petersburg to Moscow passes. Over the rest of Russia, as far as the Caucasus, there is spread out a great series of secondary rocks in horizontal strata, the heights which they reach scarcely ever passing above 200 or 300 ft. The bottom of the shallow German Ocean and the eastern counties of England are prolongations of this plain.

Hungary contains a vast plain, monotonous as a waveless ocean, 350 miles long and 100 broad, and a lesser plain 100 miles long by 50 wide. The great plain of Lombardy, the desiccated bottom of a shallow extension of the Adriatic, is 200 miles long by 50 broad. It forms the most northern rice ground of Europe.—These features of the surface of Europe are represented in one of our sections, Plate VIII., Fig. 1.

19. Fauna and Flora. — The vegetation of S. Europe is subtropical (Art. 9); here the dwarf-palm, cactus, banana, sugar-cane, the orange, lemon, citron, fig, almond, and pomegranate are grown; rice reaches the Lombard plains, tobacco and maize the valley of the Rhine as far as latitude 49°. The limit of the vine is marked northward by a waving line, which crosses France from the mouth of the Loire, intersects the Rhine about the mouth of the Moselle, passes S. of the Harz forest and to the S. of Berlin, and then runs eastward nearly on the parallel of 50° N., till it enters Asia a little N. of the Aral Sea. North of this line is the region of the apple, pear, and other of our common fruits. The olive, walnut, melon, sweet chestnut, and mulberry thrive best in the southern part of the middle zone of Europe; where also, and in the central parts, the most suitable conditions for the growth of wheat prevail—that of France alone is the source of enormous wealth; barley, oats, rye, hemp, flax, rape, and madder are more suitable to the northern tracts of the continent; and in the extreme north barley and oats alone can resist the rigour of the climate. The other classes of vegetation are extremely varied.—The Fauna is not so varied. Except a few large quadrupeds, as the buffalo in Italy, the camel in S.E. Russia, the bear, wild boar, wolf, lynx, marten, several antelopes, wild cat, and squirrel, in the middle, and in the north the elk, reindeer, polar bear, and blue fox, and one species of monkey at Gibraltar, indigenous species of this order are confined to a few small creatures. The lion existed in Scythia, that is, S. Russia, in the time of the Romans, and the beaver in Great Britain till a recent period. In prehistoric times, the reindeer inhabited the S. of France; and the elephant, hippopotamus, rhinoceros, hyena, and several other quadrupeds existed even in Great Britain, the camelopard in Greece, Sicily, and Malta.—The birds and reptiles are more abundant, but it is impossible to enter into any details concerning them.



PHYSICAL ASPECT OF ASIA.

MAP III.—PHYSICAL MAP OF ASIA.

20. THE surface contours of this great continent, which are now to be described, will be more clearly conceived of by a constant reference to the two sections which are given on Plate VIII., Figs. 2 and 3., one from N. to S., and another from E. to W.

21. Central Plateau.—Asia has a great geographical centre, to which all her mountain chains, with their dependent valleys and rivers, are related—such a centre as we have seen to exist in Europe, but not found in the other continents. This centre is the small Pamir Steppe, or plateau, which divides Chinese Tartary from Turkestan, and whose southern part in the mountain knot of Tsim-lin approaches the great bend of the Indus near Iskardo. This steppe is called by the natives Bam-i-duneah, or "Roof of the world." It contains several lakes, the largest and most southern of which is Sir-i-kol—the source of the river Amu-Daria, or Oxus—the elevation of which above the sea level is 15,603 ft., and the height of the plateau generally approaches 19,000 ft. This makes it the highest plain on the surface of the globe.

22. Divergent Chains.—From this plateau the principal chains of the continent spring out. From its S.E. extremity the great chain of the Kuen-lun or Karakorum mountains extends eastwards, and is continued in the same direction, and then N.E. to the Amur river by the chains of Nan-shan, In-shan, and Khingan; from the same point the Himalaya extend S.E. along the borders of India, thereafter their course has not been traced; but there seems no doubt that the chains of Yunnan and Southern China take their character from them. From the northern edge of the plateau there proceed, eastward, the great chain of the Thian-Shan or Celestial mountains, in the direction of Lake Baikal; northward and then N.E., the Bolor and Altai mountains; the latter, near Lake Baikal, unites with the Thian-Shan, and the axis is continued, under the name of the Yablonoi and Stanovoi mountains, by the northern shores of the sea of Okhotsk to Behring Strait; to this latter the much loftier chains of Kamtschatka seem to be spurs. The three chains, Himalaya, Kuen-lun, and Thian-Shan, are much the loftiest chains on the surface of the globe. Many of the summits pass 25,000 ft., and not a few reach beyond 28,000 ft.; the great majority may be said to vary from 15,000 to 25,000 ft. The highest on the continent, and the highest mountain on the globe, is Deodhunga, or Gaurisankar, in the Himalaya, elevation 29,002 ft.—Tengri Khan, the highest of the Thian-Shan, is 21,000 ft. in height. The Altai, on the other hand, standing like a huge wall over the Siberian plain, and but a buttress to the Thian-Shan, nowhere passes 15,000 ft., and the heights may be said to range from 5000 to 11,000 ft. Between the Altai and the Thian-Shan there does not exist, as was once supposed, a high connecting

plateau; the country is really cut deeply down by separating valleys, so that Lake Balkash is little more than 1000 ft. above the sea; while the Issil-kul lake, in the western valleys of the Thian-Shan, is only 5300 ft. above the sea; the bottoms of the valleys generally range from 1700 to 3000 or 4000 ft. only.—Turning now to the western side of the great central plateau, we have the Thian-Shan continued westwards in a short chain bearing the names of Alai and Kurata mountains, which sink rapidly down into the Turan plain of Turkestan. From the S.W. angle of the great steppe, the great chain of the Hindoo-Coosh, or Indian Caucasus, proceeds due W. along the N. of Khorassan and Persia to the southern shores of the Caspian, where it spreads out into broken lofty ridges in the Highlands of Armenia. The heights are not very accurately ascertained, but may be stated generally to range from 12,000 to 21,000 feet—the volcano of Demavend, on the south shore of the Caspian, and a landmark for sailors far and wide over that sea, has a height of 21,500 ft. From the same S.W. angle of the steppe, a continuous high chain is sent off S.W. along the N.W. frontier of India, W. of the Indus, under the names of Sufeid-koh, Suleiman, and Hala mountains, to near the shores of the sea of Oman, W. of Kurrachee; the heights range generally from 5000 to 10,000 feet, the highest mountain, Tahkti-Suleiman, "the throne of Solomon," being 11,301 feet in height. The continuity of the high land is now maintained from the neighbourhood of Kurrachee, along the S. of Beloochistan, the shores of the Persian Gulf, and the frontiers of Mesopotamia, to the cataracts of the Euphrates, in lat. 36° lon. 38°, in a great chain bearing various local names, but which is best distinguished by the old Greek name of Zagros. The heights of this great chain vary from 7000, 8000, and 10,000, to 15,000 and 17,000 ft.; and these great heights, bordering the land where the first fathers settled after the deluge, are built up of vast masses of oolitic, cretaceous, and tertiary strata, abounding in fossils. The plains of Mesopotamia, on which they look down, are covered with deposits of rich river mud, overlying a deep deposit of sandy limestone, which contains in abundance remains of shells of the same species as now inhabit the Persian Gulf. From the head of this gulf, the deposit extends 300 miles inland; and here the lieutenant of Nimrod placed the foundations, below the river mud, of the first cities, Nineveh, Rehoboth, Calah, and Resen—a case of the contact of geology and history of no small significance. The Zagros chain presses nowhere very close upon the sea; and thus a maritime belt is left all the way from Kurrachee to the mouth of the Euphrates admirably adapted for railway construction.

From the cataracts of the Euphrates westwards to the shores of the sea of Marmora, the prolongation of the Zagros chain still bears the name of Taurus given by the ancients. At the "Cilician gates," near Tarsus, it gives off a great spur, traversing Syria and Palestine, the Arabian Desert as far as the head of the Red Sea, and apparently inosculating with the mountains of Arabia, though here definite information is wanting. The Anti-Taurus is a great counterfort to the Taurus, and coalesces with the mountain region of N.W. Armenia; and from these there passes off westwards, along the southern shores of the Black Sea, a chain of less elevation, but still reaching from 3000 to 6000 ft.—this is the Laxian chain of the Greeks. Between this chain and the Taurus, Asia Minor is a mass of irregular mountain ridges, deep valleys, and small plateaux. This structure, developed to the sea-shores, renders the country utterly unfit for the construction of railways; but on the south side of the Zagros chain, from Antioch to the Persian Gulf, the country is perfectly adapted for this purpose. The mountains of Asia Minor range from 8000 to 10,000 ft., but a few reach 1000 to 2000 feet higher; highest, Argish (*Argæus*), N. of Tarsus, 13,100 ft. Lebanon and Anti-Lebanon, divided by the great valley of Cœlo-Syria, or "Hamath," are S. spurs of the Taurus, and reach to 9000 and 10,000 ft. in altitude.

The Caucasus does not seem to have a direct connection with any other chain, but offsets from it, between the sources of the Kur and Rion, effect a junction with the chains of Asia Minor. At the mouth of the Kur and Aras, a plain of 150 miles long separates it from the Paropamisan branch of the Hindoo-Coosh, at the S.W. angle of the Caspian; the true prolongation of this chain being one from 4000 to 6000 ft. high, which runs into those of Armenia and Asia Minor, by the sources of the E. Euphrates, north of Lake Erivan. M. Elburz, the highest summit, has an elevation of 18,498 ft. This chain has a remarkable conformation—very unlike that of any other, except perhaps the Alps of Abyssinia. It ascends from the northern steppes by a series of inclined plains, rising in terraces one over another to the height of 9000 to 12,000 ft., and rent in all directions by deep narrow valleys or vertical clefts, which render the higher uplands most difficult of access. Over the whole range vegetation is extremely vigorous, and profusely rich, at very great heights. Cereals grow well at 8300 ft., and yield excellent crops at 7000 ft. Hence the upland plains can support a large population with numerous flocks and herds. On the S. side, the mountains fall away with more numerous ridges and gentler slopes. The Tchatir-Dagh range of the S. Crimea is on the prolongation of the Caucasian axis, but 100 miles distant.

23. Minor Chains.—Of the minor chains of this great continent, some are mere offsets to the grand axial ridges, others fan-shaped, divergent prolongations. Of the former kind are those of Birmah, Malaya, Siam, and Annam; of the latter, the various ranges of China proper. Of those of India, two at least have a certain dependence on the Himalaya: the Khasia, reaching from 5000 to 7000 ft., which enters from the N. of Birmah, and, interrupted for 140 miles by the valley of the Ganges, is continued across the country under the name of Vindhya, elevation 3000 ft., to which the Satpoora, also 3000 ft., is but a buttress—the two determining the breadth of the peninsula; and, second, the Arrawulli range, parting S.W. from the Himalaya, dividing the basins of the Indus and Ganges, and in its S.

part reaching 6200 ft. The W. Ghauts may be regarded as almost a prolongation of this range, though there is a slight bend in the axis, and an interruption to the continuity through a short space. In Arabia the mountain ranges do not appear to have any dependence upon the chains we have described; while those of Eastern Siberia are no doubt connected either as offset chains or as parallel ranges of contemporaneous formation, with the main axis ending at Behring Strait, and facing the great terminal ranges of the vast mountain system of N. America. All the large islands of the Indian Archipelago are traversed in their greatest length by high ranges; but they do not appear to have any dependence on the continental chains.

24. Plateaux and Passes.—The most magnificent system of table-lands on the surface of the globe is immediately dependent upon the great ranges above described. The elevated region in question embraces Chinese Tartary and Tibet, the whole of Afghanistan, Beloochistan, and Persia, and the greater part of Armenia and Asiatic Turkey; and the ranges we have noticed are but the boundaries of the plateaux. That of Chinese Tartary is the largest—it is contained between the Thian-Shan and Kuen-lun, and reaches the height of 5000 to 10,000 feet in its western part; in the eastern it declines to 4000 and 3000 feet. The plateau of Tibet, on the southern side of the Kuen-lun, varies from 11,000 to 13,000 feet along the course of the Brahmapootra, as far as its great western bend, and inland reaches 15,000 feet. If, as is usually represented to us, the whole of this country is indeed a plateau of this height, it will be by far the most extensive elevated plain upon the globe. In regard to the heights upon the river there can be no doubt, as they are from recent surveys of English officers; and it is truly wonderful to find a river of the first-class actually navigated at such vast altitudes. The Yungling chain of W. China is little else than the eastern wall of this great plateau, from whose edge a few peaks rise from 5000 to 10,000 ft. higher. The Himalayan ranges are its boundary towards India. In Afghanistan, the plateau reaches a general height of 7000 ft.; on level plains at this height are situated several cities, as Cabul, Jellalabad, Ghiznee, and Candahar. To these there reach up through a gradual ascent but two practicable passes from the plains of India, across the Sufeid-Koh and Suleiman ranges — those, namely, of Khyber and Bolan, 40 miles long, and so narrow in some places that the burdens must be removed from the backs of camels to enable them to get through. Down the most northern of these, the Khyber Pass, all the conquerors of India before the British, except Tamerlane, entered the country. If both passes were now properly defended, the country would be unassailable except by sea. From Afghanistan northwards into the plains of Turkestan, there are several passes —Khawak, the highest, in lon. 70°, 100 m. N.E. of Cabul, that by which Tamerlane entered, is 13,000 ft. high; the Bamean, the lowest, 80 m. N.N.W. of Cabul, the only one practicable for artillery, is 8496 ft. high. The Russian outposts are now little more than 200 miles from this pass.

The plateau now declines westward, the table-land of Iran, comprehending Khorassan, Persia, and the southern parts of Beloochistan, being only from 4000 to 2500 ft. in elevation; its outer barriers are the Paropamisan chain on the N., and the Zagros on the S. Through these the passes are not difficult. The narrow central plateau of Armenia, against whose opposite sides the wide plains of Mesopotamia and of the S.W. shores of the Caspian press closely, which holds the great lakes of Van and Urumiah, and contains the roots of the huge mass of Ararat, varies in elevation from 4200 to 5500 ft. Towards the sources of the western branch of the Euphrates it reaches 7000 ft., and here the winter is so severe that the inhabitants retreat into cellar-dwellings. Mr Curzon tells us that the cold is so intense at this season, that when the door of one of these cellar-dwellings is opened, the moisture rushing out is instantly frozen, and falls as a fine snow-shower!

The small discontinuous plateaux into which Asia Minor is broken up by the irregular cross ridges and deep valleys (Art. 22) which traverse the country between the two maritime ranges, vary in height from 3000 to 6000 ft. On the west, around the bases of Olympus and Ida, the country sinks down into the plains of Troy and the level shores of the Propontis.

Arabia is said to form at least two plateaux, the heights of which vary from 3000 to 4000 ft., but definite information is wanting in regard to them. South India forms a small true plateau, bounded E. and W. by the Ghauts, N. and S. by the Satpoora and Nilgherry hills, and N.E. by the Balasore range; the greater part is of the average height of 2000 ft.; a small part, called the Mysore, at the back of the Nilgherries, is 4000 ft. high.—The country between the Caspian and Aral Seas, called the Ust Urt, forms a low irregular plateau nowhere exceeding 731 ft. in height.

25. Plains.—The country of Turkestan is an irregular plain, mostly barren, and destitute of fresh water, except in the basins of its rivers. The basins of the Ganges and Indus are extensive plains; that of the Ganges, 800 miles long by 200 broad, is rich and fertile: the plain of the Indus, 500 miles by 160, mostly desert. The vast plain of East China, 700 miles by 500, is formed by the widening out and confluence of the valleys of the two great rivers as they approach the sea. It is a complete network of canals and rivers. The great Arctic slope or Siberian plain is the most extensive and remarkable of the continent. Westward it becomes confluent with the European plain. From the ocean it rises southward by an imperceptible slope, till it attains, along the base of the Altai, a height of 1200 ft. E. of the meridian of Irkutsk, it becomes broken by hill ranges, and irregular in outline. The northern part is a hopeless waste; the central part produces grass, stunted shrubs, a few trees, and, in favoured spots, cereal crops and vegetables; the southern part has dense forests of vast extent, interspersed with wide glades of productive land. Everywhere over the northern and central parts, as far at least as 600 miles from the Arctic shores, immediately below the surface frozen soil is met with, and the borings shew

an alternation of coarse and fine detritus, layers of wood and peat, and skeletons of animals—sometimes the bodies preserved entire with the hair, flesh, and even the eye-balls undecomposed. These are brought to light when the banks of the rivers, undermined by floods, fall in. The wild dogs then collect in crowds to devour the flesh. The frozen soil has been pierced to the depth of 400 ft. without being passed through; and it probably continues to extend downwards till it is melted by the internal heat of the Earth. The chief animal remains are those of the mammoth (*Elephas primigenius*) and a rhinoceros (*R. Tichorhinus*). They belong to two extinct species, and so wholly unaltered is the ivory that jelly, like that prepared from the gelatine of recent bones, has been made from the shavings thrown off by the turning-lathe. So abundant are the remains, that the "fossil ivory" is an important article of trade. This wide dispersion, the covering of long hair, and the teeth, adapted for the mastication of shrubs and plants (unlike those of living elephants), shew that the mammoth inhabited the region, having a permanent abode in the southern districts, and wandering down N. to lat. 60° in search of food in the hot summer months. This explanation is strengthened by the fact, that a small species of elephant now inhabits the mountains of Nepaul, and has a hairy coat, which enables it to resist the rigour of the winter's cold. The extinction of the mammoths was probably caused by a great refrigeration of climate, brought on by a general elevation of the land along the border of the Arctic Ocean, from the Bothnian Gulf to Behring's Strait, of which there is independent evidence.

Towards the head waters of the great Siberian rivers, the summer thaws occur long before the snow and ice are melted at their mouths. Unable to escape by their own channels, the waters accumulate and spread far and wide in sweeping floods. Thus vast quantities of detritus, trees, and bodies of animals are borne away by the powerful currents, and spread out over the soil not yet thawed in stratified deposits of gravel, sand, mud, and vegetable matter, resembling the coal measures of Europe. When at last the sea and river mouths are freed from ice, part of these detrital matters are carried seaward by the floods, and deposited along the shores of the remotest part of land. Thus, no doubt, have the animal remains been so widely dispersed, finding their last resting-place even on the far-off shores of New Siberia. Here they are associated with great quantities of drift timber, are collected by the hunters during winter, and brought over on sledges before the sea is open. They are found as high up as 270 ft., which is also the height of Yakutsk, though 600 miles inland; and it is hence obvious that the troubled waters in which the remains were transported, must have extended to this distance up the Lena valley. The frozen stratum of Yakutsk, 400 ft. deep, is 130 ft. below sea-level, yet it was no doubt once near the surface, when the old sea-line was somewhere in this latitude.

26. Depressions.—Two great depressions occur in Asia, to which there is nothing else like on the surface of the globe. The deepest of these comprehends the entire valley of the Jordan in Palestine and the basin of the Dead Sea. The singular structure of this region is illustrated by two of our sections, Plate IX., Figs. 3 and 4—one in the direction of the depression, and the other transverse to it. Section No. 4 passes from the Mediterranean through Jerusalem to the mountains of Moab. Eastwards from Joppa, the maritime plain, or plain of Sharon, has its first marked rise near El Kubâb, whence the country swells rapidly upwards into the central plateau, which stretches N. and S., with unbroken continuity, from Carmel and the plain of Esdraelon or Jezreel to the south of Hebron. Its surface at Jerusalem is 2400 ft. above the Mediterranean; the Mount of Olives is 300 ft. higher; and thence by Bethany, at the back of the Mount, the country descends rapidly, by terraces and slopes, to the Dead Sea, which is 1298 ft. below the Mediterranean, and therefore 3698 ft. lower than Jerusalem, and 3998 ft. lower than the top of Olivet. The summit of the gorge by which "the brook Kedron" discharges its waters is 1200 ft. above the lake. From its eastern shores the mountains of Moab spring suddenly up to the height of nearly 3000 ft North of these, and E. of the Jordan, the plateau of Hauran or Bashan stretches to the base of Hermon, which is 10,000 ft. in height. This high range is prolonged N. in the Anti-Lebanon.—Section No. 3 is in the direction of the depression, which extends from the base of Hermon to a considerable distance S. of the Dead Sea, through a wide level tract called El Ghor. From the S. slopes of Hermon the country falls rapidly, so that the head of the plain N. of lake Merom is only 500 ft. above the sea level. The "waters of Merom" are only 50 ft. above sea level. Thence southwards the depression rapidly increases to the sea of Tiberias, which is 652 ft. below the Mediterranean. Thence to the Dead Sea, the Jordan has a fall of 646 ft. in about 60 miles of direct distance, but of 160 miles reckoning the windings, with a current varying from 2 to 5 miles per hour, not reckoning the rapids, which are numerous. From the southern extremity of El Ghor, 97 ft. below the Mediterranean, the country rises towards the Red Sea through the Wady-el-Arabah to a maximum level in the middle, at the water-parting, of 525 ft.; thence there is a gradual descent to Akaba or Eziongeber, at the head of the N. fork of the Red Sea. There is thus a difference in level between this water-parting and the Dead Sea of 1823 ft.; while the summit level between Acre and the sea of Tiberias is 1950 ft., so that, if the valley were filled with water, the discharge would be by the Red Sea. But there is no evidence that the Jordan ever discharged in this direction. In time past, as now, the great evaporation in this deep, sheltered, and hot valley, has been sufficient to dissipate all the fresh water, and to preserve to the "sea of the plain" the character of the "Salt Sea." To explain the existence of this deep *crevasse*, the most profound on the surface of the globe, there is no need to call in the aid of an earthquake. There is no allusion in the sacred narrative to the occurrence of anything

remarkable from the parting of the patriarch with the heavenly visitant, till the time when, in the early dawn, he looked down from the heights of Hebron upon the burning plain. The striking aspects of the country were no doubt impressed upon it at the time of the elevation of the great mountain axis, limiting on the west the Syrian and Arabian deserts, and the plateau of Hauran.

The water of the Dead Sea is incapable of dissolving any more salt, that is, it is saturated with salt; and it contains no life, animal or vegetable; the powerful microscopes of Ehrenberg detected only certain fresh-water *infusoria*, plainly derived from the Jordan. We know of at least four other lakes thus saturated with salt and without any form of life—Urumiah in Persia, Tuz Gol in Asia Minor, Elton in S. Russia, and the great Salt Lake in North America.

The Caspian Sea is the lowest portion of a much wider but less deep depression. The surface is 83 ft. 6 in. below the Euxine, that is, the mouth of the Volga is by so much lower than the mouth of the Don. The Aral Sea is 36 ft. above the Euxine, and therefore 119½ ft. above the Caspian. Over a vast area conterminous with the present Caspian, there is spread out a deposit of sandy limestone filled with shells, such as now inhabit the Caspian, and quite unlike any fossil assemblage in other parts of the globe. This deposit has been called by Sir R. Murchison the Aralo-Caspian limestone. It rests on tertiary strata containing true oceanic forms; hence the ocean had access to the area just before this limestone was thrown down. Now, in a few places on the western borders, a mixture occurs of marine and brackish-water forms; and it is hence inferred that a connection with the ocean took place to the westward of the present Caspian. The limits of the area of the former Caspian are perfectly defined by this limestone with its fossils. It embraced the area of the present Euxine, Azof, Caspian, and Aral Seas; it occupied the great plain of Turan towards the Paropamisus and West Altai; it projected great bays and gulfs into Siberia almost as far as Tobolsk, and in Russia as far as Nizni-Novgorod; whence S.E. and S. for 1000 miles, its W. boundary was formed by the high right bank of the Volga, which rises from 200 to 400 ft. above the left bank—the extreme S.W. limit reached to the great bend of the Danube at Rassova. The area so limited was about three times the size of the present Caspian. A separation from the ocean seems first to have taken place on the S.W. border, where the mixture of fossil species occurs, the hardy marine creatures having continued to exist for a time with their brackish-water associates. At a later period, an elevation towards the E. separated the Caspian and Aral Seas, the border of Aralo-Caspian beds (*a a*, Fig. 16) fringing the older miocene strata (*b*) of the Ust Urt plateau (B), the Caspian (C) still continuing united to the Azof Sea and the Euxine. That a discharge took place westward by the Bitter lakes and channel of the Manitch river into the sea of Azof seems highly probable. Floods from the Don ascend this channel 150 miles; through the remaining 200, up towards the Bitter lakes, scarped heights on both sides, with salient and re-entrant angles, at a level independent of the existing stream, seem to shew an old channel of discharge. The strait or point of discharge fixed upon is 70 miles from the Caspian, and 80 ft. above the sea of Azof, that is, 163½ ft. above the present Caspian. If the Caspian again stood at that height, its area would nearly reach the old limits. From such a height, at least, it has shrunk to its present dimensions; but there is no evidence that the desiccation is still going on. The processes of waste and supply have attained to an equilibrium.

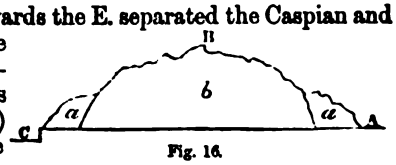
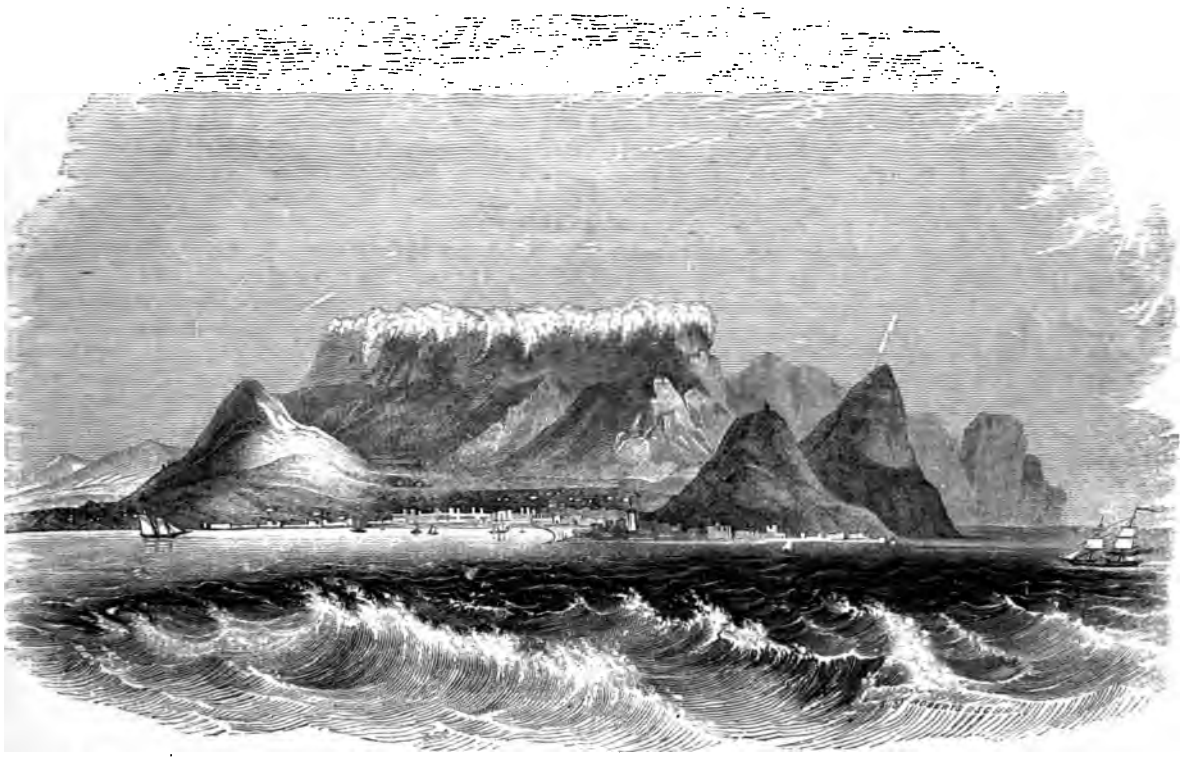


Fig. 16.

A, Aral Sea. C, Caspian.
B, Ust Urt plateau.
a a, Aralo-Caspian beds.
b, Miocene tertiary.

26*. Climate. — The surface contours above described influence the climate, the productions, and the relations of the people in a remarkable degree. The central mass of high land interferes with the aerial currents and the distribution of heat and moisture. The warm currents from the south and the cold from the north cannot effect an interchange; both are alike arrested, and deflected back across the countries whence they came; and thus the heat on the south side of the great barrier, and the cold on the north, are both exaggerated. The warm winds from the Indian Ocean deposit much of their moisture on the low outer chains against which they first impinge. These are clothed with luxuriant forests and a prolific vegetation, while the inner and loftier chains are bare of trees, and the high plateaux and northern plains are almost without wood. Hence arise the extremes of temperature, and the wondrous contrasts of vegetation, on opposite sides of the continent.

The food, the dress, the dwellings, and general social state of the Asiatic tribes, are affected by these conditions. Many of them are thus placed beyond all contact with those civilizing influences which have developed the resources and moulded the character of the other nations of this great continent.



PHYSICAL ASPECT OF AFRICA.

MAP IV.—PHYSICAL MAP OF AFRICA.

27. Mountain Centre.—Africa differs in its physical structure from all the continents except Australia. It has high mountains along its borders, and an interior without continuous ranges, and only moderately elevated in some parts. The two bordering ranges have a common origin in a mass of high land which occupies the whole breadth of the continent in its most southern part. Here, from a maritime border 8 to 20 miles wide, the land rises northward in three terraces successively higher, and each bordered by a range of mountains running E. and W. Narrow gorges, or "kloofs," in these, form the passes from terrace to terrace. The third terrace or Great Karroo, has a mean height of 3000 ft., and the Nieuweld range bounding it on the N. is the loftiest of S. Africa, and is generally snow-clad—highest point Spitzkop or Compassberg 8500 ft. North of this great range there is a broken country as far as the Orange river, having a general height of 3500 ft., but rising to near 4000 ft. where it backs up against the coast ranges. North of the Orange river the great Kalihari desert stretches 1000 miles N. to the parallel of 18° S., with a width of 300 miles. It has a general level of 3000 ft., is broken by low ranges of hills, and is in parts covered by bushes, but without water except after thunderstorms. This structure is illustrated by the annexed cut (Fig. 17). Herein Africa differs from Australia, which is very broad along the south, and has no elevated mass of land connecting its coast

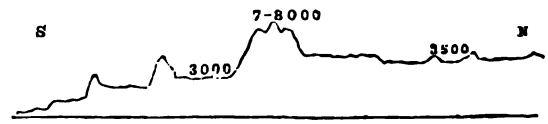


Fig. 17.

ranges—these, indeed, are widely separated by the great Australian Bight on the S., and Carpentaria Gulf on the N.

28. East Coast Range.—Bending round from parallelism to the S. coast, the great chain of S. Africa turns N.E. and forms a magnificent background to Caffraria and Natal, as far as the banks of the Limpopo river. Here it bears the name of Kathlamba or Drakenberg mountains, and rises in some points as high as 10,000 ft. Broken through by this river the range is resumed under the name of Matoppo, an irregular group reaching to the Zambezi, on the north side of which, towards Lake Nyassa, the range has the four peaks of Morumbala, Clarendon, Milanje, and Zomba, respectively 4000, 6000, 8000, and 7000 ft. in height. Thence the chain is continued in broad parallel ranges as far as the Equator, near which are the two highest mountains yet discovered in Africa, Kilimanjaro and Kenia, 20,000 and 18,000 ft. in height, and permanently snow-clad. Northwards through 5 or 6 degrees of latitude information fails us till we

reach a southern tongue of the great plateau of Abyssinia, where we are again on known ground. But there can be no doubt that through this space the chain is continuous.

The plateau of Abyssinia is in the form of a triangle, with the base to the N. and apex southwards; its general height is 7000 ft., above which the mountains rise 6000 to 8000 feet more; highest point Abba-jared 15,000 ft. The eastern edge is more elevated than the western, as shewn in the fall of the Nile tributaries; and as the country is subject to tremendous floods in the wet season (June till October), and the strata are soft, gorges 1000 ft. deep, with perpendicular sides, have been cut into the plateau; while, by the rains alone, or by streams at former levels, the surface is cut up into isolated hills and ridges of fantastic forms, and of most difficult approach, having in many cases the appearance of fortresses reared by the hand of man. The eastern edge of the plateau, unbroken by a stream on account of the slope being directed W., is uniform and steep towards the Red Sea and Somauli country. From the north of Abyssinia the great coast range is continued without interruption on the E. of the Nile through Nubia and Egypt, rising in many places as high as 5000 to 6000 feet, and terminating in the Mokattem range, on whose declining ridges, ere they drop into the Suez Desert, part of the city of Cairo is built.

29. West Coast Range. — Returning now to the great mountain centre of the south, we find that as on the east so on the west, it gives rise to a considerable chain, which parts from the Nieuweld range, and at first in two parallel ridges, after in but a single chain, continues its course along the Atlantic coast as far N. as lat 5° N., where the Quorra (Niger) issues towards the Bight of Biafra. In lat. 20° to 23° S. there are some high peaks, as Oniatako 8750 ft.; but from the parallel of 15° S. the high border retires inland, and the coast, as in Benguela, is low and marshy. High ranges, however, as the Talla Mogango and Mosamba mountains, border the inland plains, and give origin to many feeders of the Congo. North of this river the Sierra Complide forms a continuous range not far from the coast, and terminates near Calabar in the lofty group of the Cameroon mountains, which reach an extreme height of 13,700 ft. This group seems to send offsets towards Lake Tsad, near the centre of the continent, where the Alantika and Mindiff peaks rise to 9000 and 8000 ft.; but little is known of the relations of these groups.—Westwards, the lofty isles of Fernando Po and St. Thomas, respectively 11,040 and 7000 ft. in height, have a manifest dependence on the Cameroon group. From the W. bank of the Quorra in lon. 7° E. to lon. 11° W., the coast range is continuous under the name of the Kong mountains, but the elevation does not pass 3000 ft.—offsets to the south give a rocky character to the coast through a space of 1000 miles. In 11° N. and 11° W., in bending round N., a mountain-knot is formed, and a great river centre, unique in respect of its nearness to the coast. Here plains 300 miles wide, and reaching through 10° of latitude, separate the range from the Atlantic on the west. These lie under a climate the most humid and hot on the surface of the globe, and they are in consequence overspread by a vegetation of unrivalled luxuriance. East of these plains low offsets of the Kong range dip into the margin of the great Sahara, all traces of a coast range vanish, and the western boundary of the vast desert is formed throughout its whole extent by the margin of the ocean, into whose shoaling waters the drifting sands are carried far seaward by the violent east winds.

30. System of the Atlas.—In lat. 30° N. the chain of the Atlas springs suddenly up on the N.W. confines of the desert, and extends through 1500 miles of longitude along the N. coast of the continent, with a breadth of 300 miles. The chain proper terminates on the sea-coast of Tunis; but lower offset heights extend S.E. along the coast of the great Syrtis, rising in the plateau of Barca to 1500 ft., with a breadth inland of 200 miles. This high ground melts away southward to the desert, and eastward into the level plains near the mouth of the Nile, where it sinks to a few hundred feet and narrows to 70 miles.

The Atlas consists of two main ranges, the outer or Little Atlas, and the inner or Great Atlas, in some parts connected by counterforts enclosing wide basins, in others separated by longitudinal valleys of great extent. The northern offsets enclose between them fine arable tracts called the Tell, in many parts forming by their coalescence wide plains bordering the Mediterranean. The inland heights are mostly pasture plateaux; and the inner range abounds in rich woods of the cork tree, oak, pine, poplar, olive, &c., the abode of the lion and panther. The highest summit, Miltsin, is at the extreme S.W., 27 miles S.E. of Morocco, elevation 11,760 ft.; Aouress, S.W. of Tunis, is 7583 ft. in height. S.W. of this mountain there is a wide region running westward from the coast, depressed 150 to 200 ft. below the sea-level, the basin of a dried-up gulf, connected by a strait to the gulf of Khabs, and indicated on our map by dotted lines (Shott Kebir, &c.) On either side of the old strait the mountains rise from 3000 to 6000 ft. None of the Atlas mountains are permanently snow-clad. A counterfort from the outer range is given off towards Gibraltar Strait.

31. Plains.—Much of the interior of Africa is yet unknown to us; in regard to most of it our information is scanty. North of the Kalihari desert, from the parallel of lake Ngami to a distance of 700 miles, there are open grassy plains on about the same level as the desert, and across which many tributaries of the great Zambezi wander feebly; and on which, in the heart of the continent, the head waters of this river and those of the Congo have, according to Livingstone, a common source in marshy tracts flooded in the wet season—a singular structure, in virtue of which, were it not for the great falls on the Zambezi, a small vessel could, at this season, actually sail across the continent from the Indian Ocean to the Atlantic, by ascending the one river and descending the other. The plains increase in height westwards. The town of Shesheke, at the mouth of the Nioko, is 2842 ft. above the sea; Linyanti, at the S.

elbow of the Chobe, 3520 ft.; Lake Dilolo, near the strange water-parting, 4700 ft.; E. and N.E. the country falls away in general level, points upon the river, as at Kafue and Loangwa, being a little less than 1000 ft.; lake Nyassa, 1522 ft.; lake Shirwa, 2000 ft. Whatever may be the general level of the region west of Nyassa, we know from the latest discovery of Dr. Livingstone, that it is dominated by a higher country to the north. From the plain of the Leeambye, or upper Zambezi, the edge of this high country is seen as a mountain range trending nearly E. and W.; and on ascending to it the traveller finds himself to be upon a wide irregular plateau, 3000 to 6000 ft. above the Zambezi plain, having like Abyssinia its eastern edge higher than its western, so that its waters are thrown off W. and N. This plateau has a high range on its east side, has much forest, and towards its western part a series of lakes approximately represented on our map. On this plateau somewhere the source of the Nile must lie, not farther S. than lat. 11° S., since this parallel marks the southern boundary of the plateau. The after course of the great river, till it issues from the Albert Nyanza lake discovered by Baker, is still unknown to us (Feb., 1871). The general level of the plateau must fall rapidly northwards if the heights given for the great lakes are correct: Victoria Nyanza, 3300 ft.; Tanganyika, 2800 ft.; Albert Nyanza, 2500 ft. In the vicinity of these there are several high mountains: a group W. of the Albert lake was estimated by Baker at 10,000 ft.—Of the country W. and N., from 5° S. to 10° N. and 20° in breadth, we know almost nothing; but there can be no doubt that the high plains, thus far continuous from Cape Colony, now sink down into the low and level tracts of Soudan, near the centre of which is placed the great lake Tsad, elevated only 850 ft. above sea-level. This is a fresh-water lake, though forming a closed basin. To the south of these plains the edge of the plateau is placed by Dr. Barth, to whose researches is due nearly all we know about the region of Soudan, in about lat. 8° N. near the Alantika and Mindiff peaks, which stand in isolated positions in advance of this edge. On these plains the Quorra and Tshadda-Benue are navigable through their entire course, the latter 800 miles from the sea being half a mile wide and 10 ft. deep; and so level is the country towards its source, that at the time of the tropical rains, small vessels might pass across the flooded lands into the channel of the Share river, and so down N. into lake Tchad. The Soudan plains are rich and fertile, with a vast extent both of arable and pasture land, and support a numerous population.—The profile of the continent in this part is shewn in Plate VIII., Fig. 4.

32. The Deserts.—North of these wide plains of Soudan, the desert plateau of the Sahara rises to an elevation of 800 or 1000 ft. more. Its general level is about 1600 ft.; but here and there, over its wide surface, low chains of hills and higher plateaux are placed irregularly, and reach from 3000 to 6000 feet in height. About the meridian of 5° W. two plateaux divide it into the Sahel on the W., and Sahara proper on the E. This eastern part merges into the Nubian and Libyan deserts, bounding the Nile valley, on whose fertile lands their sands are constantly encroaching, just as on the W. the sands of the Sahel, the chief region of sand drifts, are shoaling the Atlantic a long way out. The whole region is without rain or dew, and uninhabitable, save in a few scattered spots, termed oäses, whose depression below the general level gives an outlet to springs, and renders cultivation possible. The water, however, is generally brackish from the impregnation of the clay subsoil with saline matters. Beds of recent marine shells have lately been discovered in many parts of the Sahara, and it has hence been concluded that much of this desert is the desiccated bottom of an ancient inland sea, comparable in area to the Mediterranean. If such a sea really existed, the climate of S. Europe must have been much cooler than at present, and the Alpine snows, which are now periodically melted by the breath of the Sirocco, must have then descended to a much lower level. Now it is remarkable that there is evidence of the former descent of glaciers to levels lower than the present, from facts observed before the existence of a Saharan Mediterranean had been suspected.

33. Relative Aspects.—On a review of the physical aspects of this continent, it will be seen that they correspond strikingly on opposite sides of the Line. There are the vast grassy plains of Soudan and Senegambia on one side, and those of the Zambezi basin on the other; the rainless and desert regions of the Sahara and Kalihari; and the terraced mountain regions of the Atlas and Cape Colony, with their dependent belts of fertile land.



PHYSICAL ASPECT OF NORTH AMERICA.

MAP V.—PHYSICAL MAP OF NORTH AMERICA.

34.—PHYSICALLY considered, N. America may be divided into four regions; a narrow band of low land on the coast of the Pacific, a mountain region in the west, vast central plains, and a hilly region in the east. An attempt is made to shew these features in our section, Plate VIII., Fig. 5, which will help to call up a livelier conception of the surface outlines.

35.—The Andes of the southern portion, and the Rocky Mountains of the northern, are the proper axis of the continent, the direction of which has determined the development of the land. In all their physical relations these are truly one chain; yet a striking interruption occurs just where the breadth of the mineral axis is least, and where, of all other places, such interruption best subserves the interests of nations. At the isthmus of Panama, the breadth is only 48 miles due N. and S., and the surface sinks to 299 ft. above half-tide level in both oceans; across this depression a railway has been carried from Aspinwall on the E. side of Navy Bay to the city of Panama; and various schemes are still in agitation for carrying a canal across at a point where the depression is not much different from that of the railway summit level, which is 254 ft. In the Caribbean sea the rise of tide is no more than from 6 to 7 ft., in the bay of Panama as much as 19 to 25 ft.; so that the difference of level between the two seas may vary from day to day between the extreme limits of 13 and 32 ft., while if half-tide occurs at the same time on both sides, the levels of the water in the two oceans will be the same. But such conditions can only exist for a few minutes; and the effects are practically the same as if the two oceans were permanently at different levels, as was long supposed. The apparent difference arises solely from the peculiar way in which the localities are related to the progress of the tide-wave in the Atlantic and Pacific oceans.

The low hills which traverse the isthmus, and in which these convenient breaks occur, are about 1000 ft. in height. The range rises northwards, but only to sink again; for, in the route of 12 miles from lake Leon, which communicates with lake Nicaragua, to the Pacific, a depression in the ridge of only 220 ft. above this ocean occurs. The San Juan river, which runs E. from lake Nicaragua, has, however, two falls, which are got over by portage, and might easily be surmounted by short canals. The isthmus of Tehuantepec in lon. 95° W. forms another depression, across which both a railway and a canal have been proposed. But to the north of this the plateau of Mexico, lifting itself rapidly upwards, forms an impassable barrier between the two seas, never to be surmounted by any such work of man. Its E. and W. edges, with the mountains rising along them, or planted upon the plateau itself, form the double range of the Mexican chain; in this part the plateau has an average height of 7000 ft., and above this the peaks rise from 8000 to 10 000 feet higher. The

western chain bears the name of Sierra Madre, the eastern has no special name that we know of; geographers call it the Mexican chain simply. The city of Mexico is 7470 ft. above the sea, and in this part and northward so level is the surface of the plateau, that a wheel-carriage can be driven along it for 1400 miles. The plateau narrows northwards, and about lat. 35° the two chains coalesce to form the Rocky Mountains, a broad chain with lateral ranges and intervening longitudinal valleys. The lateral ranges are sometimes parallel for great lengths, and the inclosed valleys are plateaux. In other cases they coalesce and form mountain-knots, the most eastern ridges descending into the Mississippi valley, as successive plateau-buttresses to the main chain, and throwing off spurs at right angles still further into the eastern plains. One of the most important groups of the Rocky Mountain system is that called the Wind River mountains, lat. 44°, lon. 110° W., the great river centre of N. America. Here, near the base of Fremont's peak (13,568 ft.), some of them no more than a few paces apart, are the sources of the Yellowstone, Missouri, Big Horn, Platte, Colorado, and Lewis, a principal branch of the Columbia. Here also occurs the most important pass, Fremont's or the south pass, between lat. 42° and 42° 40′, where the axis declines to a height of 7489 ft., affording a very gradual ascent on either side, and a ready access to the interior plains of the great basin. Up the Platte river basin, and across this pass, the great Pacific railway, one of the grandest works of the age, has been carried. Summit level in the Wahsatch mountains 4411 ft. The highest group occurs in about lat. 52°, where several peaks rise from 15,000 to 17,000 ft. The chain diminishes in height towards the north till it terminates in considerable offset and fan-shaped ranges, which descend towards the Arctic ocean and Behring's Strait.

36.—Bound on to this great back-bone chain of the continent by a high plateau, there is another lofty range close to the Pacific coast. Its lower and most southern part is parallel to the Sierra Madre, and traverses the whole of lower California from Cape St. Lucas, its southern extremity, lat. 23° N., to St. Bernardino mountain near San Diego in lat. 34° N. The heights vary from 1000 to nearly 5000 ft. till lat. 28° is reached, where occurs the highest point of the chain in the Cerro di Giganta 4900 ft. high. At St. Bernardino, which reaches the height of perpetual snow, the chain bifurcates into the Sierra Nevada of California on the east and the Coast range on the west. Between them is inclosed the magnificent valley-state of California, more than three times the size of England and Wales. Towards its upper end the eastern chain seems to pass into connection with the Rocky Mountains by means of ridges bounding the great plateau about the western bend of the Columbia river. The other chain continues its course along the coast under the names of the Coast range, the Cascade range, and the Sea Alps, the outer ridges of which are broken up from lat. 46° to lat. 58° in an archipelago of rocky isles. The southern part, in the W. of California State, scarcely reaches 4000 ft.; but the heights northwards are much greater, the culminating point, mount St. Elias, in lat. 60°, being 17,850 ft., probably the highest in the whole of N. America. The chain is continued northwards towards Behring's Strait, where several mountains, as on the opposite Asiatic coast, are said to reach 10,000 and even 14,000 ft. The inner chain, the Sierra Nevada of California, reaches from 12,000 to 15,000 and 16,000 ft., and is, in most parts, permanently snowed. Between this range on the west, and the Rocky Mountains and their spurs on the east, is situated a remarkable tableland, the "American Desert" of explorers. It is elevated from 4000 to 5000 ft. above the sea, but some parts of it in the south reach 6000 ft. It is divided into two unequal portions by the Wahsatch mountains, the western being the largest. This is about 400 miles long from E. to W., and 250 miles broad. Shut out on all sides from connection with the ocean by cross ranges joining the eastern and western chains, it is appropriately termed the Great Basin. The N.E. part is, in many places, well watered, wooded, and fertile, the abode of thriving settlements. The southern part is a hopeless desert, covered with incrustations of salt mixed with sand and clay, and having numerous salt lakes, into which the streams empty themselves. The eastern portion is an arid valley covered with saline and alkaline incrustations, and traversed by the Colorado and its tributaries. By these there have been cut down, in the course of ages, cañons or gorges, with perpendicular sides of enormous depth, as much, it is said, as from 2000 to 3000 ft., and *that* through spaces of hundreds of miles. The sections of the strata exhibited in these cañons are described as most wonderful to behold. This part of the plateau descends to the maritime plains at the head of the gulf of California. In British Columbia, N.E. of Vancouver's island, there is another plateau about 2000 ft. in elevation, which falls away northwards towards the wild desert tracts of Walrussia.

37.—The region of the continent to the eastwards of the Mexican and Rocky Mountains is of much simpler structure. It consists of an immense plain stretching with almost unbroken continuity from the gulf of Mexico to the Arctic ocean, and bordered through a small extent on the east by the Alleghany mountains. The plain has two slopes, one to either sea. These slopes are determined by a series of undulating heights under the name of the Missobay hills and Black hills, with the connecting "Hauteurs des Terres," in which the Mississippi has its source, the respective elevations being 1500, 1600, and 1680 ft. These lie immediately west of lake Superior, the height of which above the sea is 640 ft., or 1040 ft. lower than lake Itasca, the main head of the Mississippi. Many parts of this great water-shed are, however, lower than these heights, being only 700 ft., and pass insensibly into both plains. The southern plain rises so gradually that the heights mentioned appear but gentle swellings of the ground. At St. Louis, where the Missouri enters, the elevation above the sea is only 380 ft., though the distance to the mouth of the Mississippi in a direct line is 700 miles. From this point the plain rises more rapidly, and the rivers have several falls; till, along

the line of heights, the two plains coalesce. Along this water-shed the heads of the great rivers flowing opposite ways could be easily united. The overflow of lake Itasca could be carried with the greatest ease into the North Red river, traversing lake Winnipeg, and entering Hudson's gulf; and this same river, with like facility, could be united with the St. Peter's, a head stream of the Mississippi. The Missouri, where 600 miles from its source, already an immense river, it is deflected S.E. by a low range, could be connected by a cut of a few miles with a great bend of the Souris or Mouse river flowing northwards. Further east rivers flowing opposite ways unite naturally; after heavy rains, or a sudden melting of the snow, small vessels can pass across the flooded flats at the head of the Illinois into streams entering lake Michigan. A vessel which had sailed from the gulf of Mexico could, in these circumstances, pass into the St. Lawrence and so into the Atlantic through the heart of N. America—a singular feature having a striking analogy with the conditions existing naturally and permanently in S. America.



FALLS OF NIAGARA.

The wide prairie plains of the Mississippi are broken through a short space only by a low range of hills called the Ozark mountains. They extend between the Missouri and Arkansas rivers about 150 miles, and are wooded to their summits, which nowhere pass 2000 ft. The eastern part of this great plain is well wooded, has an immense extent of the richest land, and a surface delightfully varied by rolling heights and wide dales. The central parts consist of perfectly level tracts or savannahs, and "rolling" levels, called prairies, without trees, but covered with long grass intermixed with a few flowers and shrubs; kalmias, azaleas, and rhododendrons, representing the heath tribe of Europe and Africa, appear along the streams. Westward the country rises towards the mountains, whose ridges receive the residue of rain remaining in the clouds which have passed across from the Pacific; and there is thus in this part much barren and desert ground. The southern part of the plain is occupied by immense level and often swampy tracts little raised above the sea, and adapted from its hot humid climate for the growth of rice, the sugar cane, and sea-island cotton. This vast plain derives its rain chiefly from the gulf of Mexico. The eastern trade-wind, entering from the Atlantic, passes across this gulf loaded with the abundant moisture which its high temperature enables it to dissolve; striking the lofty Mexican plateau, which stretches from lat. 18° to lat 40°, it is deflected north, and finds a ready passage up the great plain, upon whose expansive and gladdened bosom it deposits its rich and fertilizing load.

The northern or Arctic slope has, in Canada East and Labrador, and along portions of the Arctic shores, low ranges of hills; but most of it is very level, covered with countless lakes, and intersected by a perfect network of streams. Its vast breadth in the north, and its contact with an ocean almost constantly frozen, give this whole region a rigorous climate; so strangely rigorous that northwards of the latitude of Quebec (which is the same as that of Nantes), wheat will not ripen till we reach the sheltered valleys east of the Rocky Mountains, where the limit of this cereal extends much farther north. The greater mildness of the climate towards the west is still more strikingly shewn by lines on the map of "ground permanently frozen," and "northern limit of trees," whose respective terminations on the east coast correspond with the latitudes of Derby and Inverness; while, on the west coast, they terminate in latitudes respectively the same almost as Upsala and Tornea.

38.—Returning to the great southern plain, we find it bounded on the east through most of its extent by the Alleghany mountains. This range has its origin in the northern plains of Alabama and Georgia states, and runs nearly parallel to the Atlantic coast through the whole extent of the eastern states, terminating in Maine, or perhaps more properly in Gaspé promontory at the mouth of the St. Lawrence. Subject to local deflections the direction is N.E. and S.W. The distance from the Atlantic varies from 50 to nearly 200 miles. The length is about 1200 miles, and the breadth occupied by the several ridges and intervening longitudinal valleys is about 100 miles. The highest summits are found in the group of the White mountains in Maine, and in N. Carolina. The name is applied properly only to the middle portion in Virginia and Pennsylvania, the other parts having local names, as Blue Ridge, Laurel, Cumberland, Catskill, White mountains, &c.; but geographically and physically the range is one throughout the limits named.

The Appalachians are distinguished from most other mountain chains by the absence of a middle dominant ridge or axis, to which lateral ridges on either side are subordinate and equally related. Such an axis is shewn in the annexed cut, Fig. 18. On the contrary, there are three, four, or five ridges alike eminent and entitled to be called the chief. This arises from the arrangement of the strata in enormous flexures, the convexity



Fig. 18.



Fig. 19.

forming the mountain ridges, and the concavity the valleys, as in the annexed cut, Fig. 19. This structure prevails more in the middle and southern portions, which consist of long parallel ridges and valleys with a uniform level outline of the summits, and an entire want of rocky crests; yet the crushing and fractures of the folds produce in many places rough and rocky ground, and there are many rocky and picturesque gorges by which the streams of the long parallel valleys find passages outwards E. and W. Igneous rocks, granites, porphyries, and greenstones shew here and there along lines of fracture. They probably exist in great force below the flexured beds, whose elevation and contortion is due to the transfusion among them of these igneous rocks in a melted state, the elevatory forces not having been sufficiently intense along these lines to break up the entire crust and bring these rocks to the day. The sedimentary flexured beds belong to the silurian, devonian, and carboniferous systems; and it is certain that the movements which gave to the chain its present outlines took place after the coal period, and before the deposition of the new red sandstone.

The country east of the Alleghanies has a peculiar structure. The maritime part consists of a belt of low land, in many places marshy, 150 miles broad in its southern part, but narrowing gradually northward, and terminating on the New England coast, where it is represented by low islands near the shore. Similar islands bound it along the coast, their lengths being often 30 miles, while the breadth is no more than 1 or 2, and the elevation only a few feet above the highest tides. Between these and the mainland there are navigable passages always calm, and much used by trading vessels. This tract is called the Atlantic plain; it sweeps round westwards through Georgia, Alabama, and Mississippi, bounding the Alleghanies on this side, and becoming confluent with the great plain of the Mississippi valley. It consists entirely of river and sea deposits, and forms the rice grounds and the cotton and sugar plantations of the south. It is the only unhealthy region in the States; its malarious exhalations tend to produce fever and ague. This plain is succeeded westwards by an undulating region, called the Atlantic slope, raised 200 to 300 ft. above it, and markedly separated from it by a ledge of primary rock (granite or gneiss), over which the rivers descend in falls or cataracts, and which thus marks the head of the navigation. Here, to the east of this ledge, are situated all the large cities of the eastern states from New York by Milledgeville to Montgomery, as Philadelphia, Trenton, Baltimore, Washington, Richmond, Raleigh, Columbus, &c.—an interesting example of how much influence are geographical conditions in determining the aggregation of the inhabitants of a country around particular centres. The ledge of granite still bounding the narrowing plain, strikes the coast in New England, and there forms the sea-cliffs. This rock covers wide areas in New England; and in Canada, Labrador, and the Arctic regions attains an enormous development.—The Atlantic slope stretches upwards to the base of the mountains. It is about 100 miles wide, has a delightful climate, and is the region of the upland cotton, tobacco plant, and other rich products. Upon it in Georgia, Alabama, the Carolinas, &c., tertiary deposits cover the granite and old slates; northwards in Virginia, Pennsylvania, &c., immense tracts of anthracitic coal occur upon it. This coal burns without smoke, and hence the delightful purity of the atmosphere in the Atlantic cities. In the western states, between the Alleghanies and the tertiary plain of the Mississippi, there is another field of coal, but of the ordinary bituminous variety. It is of immense extent, having an area considerably larger than the whole of Great Britain and Ireland; the coal is often most accessible, many of the principal seams being worked by horizontal adits. Lead exists in enormous quantities in N. Illinois, Wisconsin, and Iowa; copper in Upper Michigan and in the British territories N. of lake Superior. The latter is associated with trap rocks, and is in the state of native copper, in masses usually too large to be removed, and which it is almost impossible to break up by blasting or otherwise. Gold is found in considerable quantities in the southern Alleghanies, in a narrow band of schistose rocks—total value of produce since the first working of the veins about 3½ millions of pounds sterling; but these workings have been cast into the shade by the gold discoveries of California.



PHYSICAL ASPECT OF SOUTH AMERICA.

MAP VI.—PHYSICAL MAP OF SOUTH AMERICA.

39. Contours.—South America, like the northern part of the continent, is naturally divided into four regions of distinct physical character. On the Pacific coast, through 4000 miles of length, and from 50 to 150 of breadth, there is a belt of comparatively low and flat land. This is backed by a great plateau supporting lofty mountains; vast central plains form the third region; the fourth, in the east, consists of hilly tracts and lesser plateaux. These contour features are shewn in Plate IX., Fig. 1.

40. Maritime Belt.—The maritime belt on the Pacific is several hundred feet above the sea, and is traversed by low hill-ranges parallel to the coast, and by spurs from the Andes dividing the basins of the short mountain streams. The N. and S. parts are well watered and fertile; but the middle portion, from 8° to 30° S. lat., is a sandy or stony desert, except a few narrow strips irrigated from tanks which are filled by the swollen streams. Though much of it is otherwise useless, its mineral wealth in copper and other metals is unbounded.

41. System of the Andes—(*a*) *Patagonian Andes.*—The Andes form the western mountain region—a chain, perhaps, the most remarkable on the globe for its length, persistent height, continuity, and internal structure. From its southern extremity in lat. 56° to the tropic of Capricorn it is a single chain. Thence to the isthmus of Panama there are several parallel ranges of peaks or cordilleras supported upon a continuous plateau of an altitude varying from 10,000 to 12,000 ft. Cape Horn or Hoorn, on the most southerly of the countless islets of the Fuegian archipelago, is a cliff of dark slate 600 ft. high, from behind the summit of which a mountain rises steeply to 3000 ft. On Tierra del Fuego the mountains reach 7000 ft; on the mainland northwards they are lower, the mean height being about 3000 ft. The tops, if not snow-clad, are covered with peat mosses, the lower slopes with brown beech woods. N. of Sansalid frith on the N. side of Magellan Strait, the Patagonian Andes assume that continuous unbroken character which the chain after preserves as far as the tropic; the height varies from 3000 to 8000 ft. The mountains are thickly wooded, and press close upon the coast, which is hence bold and rocky, and bordered by an archipelago of rocky isles, with navigable channels between them and the mainland.

(*b*) *Chilian Andes.*—The Chilian Andes reach from Ancud gulf to the tropic, 150 miles from the coast, 80 miles broad, and from 12,000 to 14,000 ft. in height—highest point, and highest of the whole continent, Aconcagua, 23,910 ft. It is in lat. 32° 5′ S., 100 miles E.N.E. Valparaiso, and is a huge cone of volcanic trachyte, but not now a volcano. Between lat. 30° and the tropic there occur several lesser parallel chains, or buttresses to the main ridge; but it is not till the neighbourhood of the tropic is reached, that the great distinctive features of the Andes are exhibited in the division of the chain into

two stupendous ridges or cordilleras, connected by a lofty and wide plateau. The bifurcation seems to be in lat. 22° S. on the cross-ridge of Lipez, near the peak of Llulayaca. Such a point of bifurcation or uniting again of chains has been called by Humboldt "a mountain knot." The knot here may be called that of Sancristoval de Lipez.

(*c*) *Bolivian Andes.*—N. of this Lipez cross-ridge, the plateau and its bounding ridges become perfectly defined. This is the plateau of Bolivia, 12,900 ft. in height, 400 miles long, and 60 to 100 wide. The eastern ridge is the cordillera Real, the western the coast cordillera. From the eastern in 18° S. the great snowy range of Cochabamba parts off, and runs far down E. into the central plain, so far as to give here the greatest width in the whole continent to the meridional mass of high land, the total width being more than 500 miles.

The eastern cordillera has sharp rugged peaks and serrated ridges, and is not volcanic: Nevada Sorata, 21,288 ft.; Nevada D'Illimani, 21,149 ft.; Cerro di Potosí, 17,000 ft.; City of Potosí, 13,330 ft. The coast cordillera has dome-shaped summits composed of volcanic trachyte rising through red sandstone: Sahama, 22,359 ft.; Gualatieri, 21,900 ft.; Chuquibamba, 21,000 ft.; Arequipa volcano, 20,326 ft. These heights and forms render the Bolivian Andes by far the most imposing group in the whole chain.

After a long parallelism the two cordilleras converge northwards, and form the knot of Cuzco on the cross-ridge of Vilcañota inclosing the plateau on the north, and 12,000 to 16,000 ft. in height. Though the plateau is thus a closed basin, its waters are fresh and pure. Near its northern extremity is situated one of the largest lakes in the world—lake Titicaha, 12,846 ft. above the sea, 170 miles long, 70 broad, and 120 fathoms deep in some places. It discharges S. by the river Desaguadero, 200 miles long, into lake Aullagas, 60 miles long, and from 15 to 20 broad, also fresh. This lake has no known outlet, but it was observed by the late Dr. Mathie Hamilton of Glasgow, when crossing by the southern end of this lake, that a river, not laid down on any map, issues from the S. end; and since evaporation is very trifling over the whole region, as Dr. Hamilton shews, the river cannot be thus absorbed; but it cannot discharge in any direction in an open channel, the basin being closed; therefore must it descend into rocky caverns, and so may again come to the day at a lower level, and find its way to the Pacific. If this view be correct, the Andean basin is no exception to the general rule that the water of closed basins is salt. On Dr. Hamilton's authority, the spelling of the name is here changed. "As the Mississippi," says he, "is the mother of waters, so is this great lake the father of waters, Titicaha," and not Titicaca, which has a meaning less pleasing and poetic.

The mountain-knot of Cuzco or Vilcañota is the greatest in the Andes, and contains many peaks passing the snow-line, and in it three upper branches of the Amazons have their source about lat. 15° S. Two chains running N.W. from it unite again in the knot of Huanuco de Pasco, 10° S., which has also colossal nevadas, and gives rise to the Upper Marañon. Thence through 5° of lat. there are three cordilleras inclosing two narrow elevated longitudinal valleys. The western rises above the snow-line. The three become confounded in the knot of Loxa, about 5° S., and only 7000 to 8000 ft. high.

(*d*) *Andes of Quito.*—Thence the Andes of Quito stretch due N. to the knot of Pasto in 1° N. in two nearly parallel ranges, their complete separation being only interrupted in two places by cross ridges, forming the knot of Assuay, E. of Guayaquil, 15,500 ft. high, and that of Chisinche, a little S. of Quito, where a narrow dike forms the watershed between the two oceans. Thus are enclosed the three valleys of Cuença, Riobamba, and Quito, having a joint length of 350 miles, and separate width of 30 to 40 miles. As is the rule in the Andes, each is inaccessible from the other, save by twice crossing the bounding cordillera. The celebrated valley of Quito is 200 miles long, 30 wide, and elevated 9600 ft. above the sea. The peaks visible from it form a magnificent assemblage scarcely surpassed by those of the Bolivian Andes; for though lower they are much nearer to an observer in the middle of the valley. From lat. 3° S. there occur on the eastern cordillera northwards, Pullachiquir, Borma, Quinoaloma, Sangay volcano, 17,190 ft.; Guamboya, Tungurahua, 16,400 ft.; Llanguaneto volcano, Cotopaxi volcano, 18,875 ft.; Antisana volcano, 19,130 ft.; Cayambe, whose peak, 19,648 ft. high, is exactly on the equator, and the volcanoes of Chiles and Cunilval; and on the western cordillera there are from the same point northwards, Cohopata, Chimborazo, 21,420 ft.; Cargunazo, Hiniza, Pichincha, 15,936 ft.; and Cotacache, 16,448 ft.

(*e*) *Northern Chains.*—Closing the valley, the plateau of Pasto is 10,000 ft. high; it gives off two ridges enclosing the plateau of Almaguer, and ending in the knot of Las Papas in 2° N. Here the chain splits into three ridges, those of Suma Paz, Qindiu, and Choco. The first runs N., N.E., and in 8½° N. bends E. forming the coast range of Venezuela as far as Trinidad isle, which indeed takes its character from it. Its heights in many places pass the snow-line. The Silla of Caraccas rises from the coast like a wall, though at an angle of 60° only, to the height of 8600 ft. Between this chain and that of Qindiu lies the plateau of the Upper Magdalena 8300 to 9000 ft. high; the Qindiu chain has the peaks of Hinla and Tolima, 17,900 ft. and 18,020 ft. respectively; on its northern prolongation near Gallinas Point is the Horquita peak, 19,184 ft., the highest N. of the equator. The upper valley of the Cauca, between the Qindiu and Choco ridges, is a low plateau of 3000 ft. N. of this the chains approach closely, forming the Antioquia knot 7000 ft. high, and hence the western chain is split into two ridges, one running to the isthmus, and the other to the coast eastwards. All these northern branches, however, are broken and irregular, and from the junction of the Magdalena and Cauca northwards there is a wide plain. It is with these coast ranges of the Andes system, running E. and W. through the Spanish main, that the chains which traverse the West Indian isles lengthwise seem to be in relation. These isles are probably but the fragments

of a great continental land which once united N. and S. America, broken up by the volcanic agencies still so powerful on this continent.

42. Passes.—The passes in the Andes are all at right angles to the main ridges, and not as in the Alps along the line of longitudinal valleys. It is impossible in every case, we believe, to pass across the mountain-knots from valley to valley. Many of them are very dangerous from the narrowness of the paths alongside frightful gorges, or from their passing across chasms bridged by ice or an unhewn log of timber. One of the safest and best frequented roads leads from Santiago to Mendoza, and thence across the Pampas to Buenos Ayres; it crosses the Uspallata and Portillo ranges at elevations varying from 12,000 to 14,365 ft. The other chief passes are the Pacuani, from La Paz to the Beni river, and between the Nevadas of Sorata and Illimani, 15,349 ft; Alto de Toledo, Arequipa to Puno, 15,590 ft.; San Mateo, Lima to Tarma and Pasco, 15,760 ft.; highest, Tacora, from Arica to Puno in the Titicaha basin, 18,000 ft. Most of these are higher than the tops of the highest Alps. Although the Choco coast cordillera in the N.W. nowhere exceeds 7000 ft., yet are the passes across it among the most difficult in the Andes.

43. Eastern Highlands—(*a*) *Guiana Group.*—The Eastern Highlands form two groups separated from one another by the middle and lower plain of the Amazons river. The northern or Guiana group is isolated by encircling plains. About 100 miles from the sea the country rises by several terraces, lines of old sea level, into a broken plateau 2500 ft. high. On the plateau are planted several irregular ridges running in various directions, with little apparent connection among themselves, and certainly in no way related to any other mountain group. At their descent from the plateau the many large rivers have fine falls and cataracts; here and among the rugged mountains there is much fine scenery, and there are vast primeval forests. The principal ranges are the Sierra Parima and its continuation, S. Pacaraima, highest point, Maravaca, near the source of the Orinoco, and the S. Roraima, reaching 7450 ft.—average height 5000 to 7000 ft.

(*b*) *Brazilian Group.*—The second group comprises most of Brazil and the Banda Oriental, and has an area more than half the size of Europe. It is a hilly region of broken table-lands and irregular chains, the limits on three sides being marked by falls or cataracts on the rivers. On the Atlantic border the ranges of hills are parallel to, and 20 to 50 miles distant from, the coast, along the N.E. side; but further S. towards the tropic they come close upon the shore. The interior chains have a general direction from N. to S., but there are several transverse ranges, the principal of which is the Sierra Geral and Parecis, in the S.W., where lie the sources of many large tributaries of the Amazons. Other streams have their sources at the heads of closed-up valleys, and some on the narrow central plain between the Cochabamba range and the Sierra Geral. The rivers of Brazil have their N. and S. courses through limited basins, and all but one are feeders of the great river. The small plateaux among the hill ranges reach from 1200 to 2000 ft., and the mountains rarely pass 5000 ft., the two highest on the coast range of Aspinhaco being Itambi 5980 ft., and Itacolumi 5860 ft.

44. Lowlands.—The S. American Lowlands extend between the mountain regions we have described, through the entire length of the continent; they form four regions most diverse among themselves in physical aspect, climate, and productions.

(*a*) *The Llanos of the Orinoco.*—These occupy an area of 350,000 square miles, reaching 1000 miles inland to the base of the eastern Andes on the W., and of the coast range of Caraccas on the N.; on the equator they coalesce with the plains of the Amazons without any perceptible undulation; on the N.E. they are confluent with the low maritime belt bordering the mountain groups of the Guianas. The rise inland is so gradual that 500 miles from the coast the height is only 224 ft.; the elevation nowhere seems to exceed 500 ft. The delta of the Great River is the only part wooded, and as it is nearly half the year under water, the inhabitants have their dwellings on the trees; they pass to and fro by boats, and during this season subsist chiefly by fishing. They form the last remnants of the great Carib race found on the islands and the Spanish main by the first discoverers. Other parts of the llanos are treeless, save that a solitary fan-palm rises here and there as a guide and landmark to the traveller, and that the margins of the streams nourish low bushes. The soil is a chalky loam without stone or pebble. The rains set in about the middle of April, and the great steppe, before a barren desert, whose heated and loosened soil has been driven in clouds by every wind, is speedily clothed with prolific vegetation, and becomes the scene of busy life and active enjoyment. As the season advances some tracts become inundated; and at the junction of the Apure with the Orinoco a lake is formed 80 miles by 60, and 14 feet deep. The llanos are gradually acquiring fixed inhabitants, who are engaged in tilling the best portions, especially along the borders, and in reducing to a tame state the cattle, horses, and asses which, to the number of several millions, have, in the course of ages, become wild upon these wide wastes.

It is upon the somewhat elevated S.E. border of these plains that the extraordinary bifurcation of the Orinoco takes place, unexampled in the history of rivers, whereby half of its water is sent off S.W. by the Cassiquiare to join the Rio Negro, a tributary of the Amazons, and the other continues its course N.W. in the direction of the head stream.

(*b*) *The Selvas of the Amazons are the Second Region.* In the basin of this immense river an area 1500 miles long, by 400 to 1000 miles broad, is covered by forests of tall trees, between whose huge trunks there is so dense a growth of bushes, shrubs, creeping plants, and parasites, that it is impossible to pass in many places, except by cutting a path with an axe; and to visit one village from another but a few miles distant, the Jesuits, the only missionaries who have as yet found access to these regions, have to descend a long distance down one stream and then

ascend another. Even the streams are often rendered impassable by overhanging branches entwined with climbing plants. On the higher grounds the growth is not so thick; and far from the rivers there are many open savannahs with fine pasture, and tracts also of rich land capable of easy and most productive culture. But it is only in spots that the wonderful capabilities of this fine region, with its magnificent system of navigable rivers, far surpassing anything else in the world, have been turned to any account either by the native Indian or the white man. So thinly scattered indeed is the population, that there is barely an average of one person to 10 square miles. An animated and poetic description of life in the primeval forests of this vast region will be found in Humboldt's "Aspects of Nature"—Mrs. Sabine's translation, Vol. I., p. 259.

(*c*) *The Pampas of the La Plata basin* form the third division of the lowlands. They extend 1400 miles from the Lateri-quoque lagoons of the Gran Chaco in lat. 19° S. to lat. 39° S., with a maximum breadth in Buenos Ayres of 450 miles—area about 600,000 square miles, or three times the size of France. N. of the lagoons a valley 600 miles long and 200 wide, between the Brazilian sierras and the cordilleras of the Andes, connects them with the forest plains of the Amazons, towards which almost all the waters are sent. Through this distance a gradual change takes place;—the selva is succeeded by an alternation of swampy and wooded tracts, and about lat. 20° S., where the tropical rains cease, the surface becomes drier, and trees are replaced by bushes and coarse grass. South of this the eastern parts are covered with forests of thistles 10 ft. high, and brilliant trefoil; the swampy parts, with tall reeds and canes, westwards with tufted grass and showy flowers; along the base of the Andes, with thorny bushes and dwarf trees, drawing a scant subsistence from a stony soil; here also, from the lowness and flatness of the soil, and the copious streams from the Andes, swamps and wide lagoons are formed; the ground is impregnated with salt, and many of the lakes are saline. In the dry season the plains become parched and dusty, and sand-storms are frequent. This is the season of the hurricanes, called *pampéros*, which descend from the Andes, sweep the plains with resistless force, and discharge themselves on the Atlantic coast. The weather then suddenly clears.—Besides the indigenous wild animals, vast herds of cattle and horses, the descendants of those let loose by the first settlers, range at liberty over these wide plains, which yield abundant food. They are hunted down and tamed, or destroyed for the sake of the hides and fat, hoofs and hair. In the hot season an accidental spark often kindles the dry grass and thistles, and sets on foot a conflagration so



A CONFLAGRATION ON THE PAMPAS.

rapid and destructive, that the animals have no power of escape, and perish by thousands. The farm-steadings of the Scotch and Irish settlers are now protected from these by clearing a wide space all round of everything combustible. Buenos Ayres stands on a level plain about 50 ft. above the estuary; thence the country rises imperceptibly till it attains a height of about 800 ft., and then continues level to the Andes. Under the surface soil everywhere there is a reddish indurated calcareous mud, passing into a hard marl, and filled throughout with the bones and entire skeletons of extinct quadrupeds, some species of which were of gigantic size. These are all of the same type of animals as now inhabit the region—the edentate, such as the sloth, armadillo, cavy, capybara, and others; but the existing congeners are dwarfed in comparison. These remains are associated in many places with the remains of mollusca, all of which still inhabit the adjoining sea. The whole deposit rests on old tertiary beds, with marine remains of species now extinct. This deposit seems to have formed the bottom of a shallow sea washing the shores of Brazil and the Banda, amid the quiet recesses of whose sierras, composed of red granite, red porphyry, and red sandstone, the animals now found fossil had their abode. The sea became silted up with the detritus of these rocks, and the animal remains were washed down along with it—the whole area was then elevated. Under such surface conditions the heat and rainfall would be excessive, and the forms of life most prolific. This hypothesis derives much force from the discovery of like remains in the caves of Brazil.

(*d*) The *gravel plains* of Patagonia form the fourth region of lowlands; they are confluent with the pampas in the parallel of 39° S., and extend, though with a narrowing breadth, to the shores of Magellan Strait. They consist of vast sterile plains covered with rolled gravel, broken shells, and beds of entire shells, all of the same species as now inhabit the Atlantic, mixed with which are bones of mammifers now extinct. The surface forms four terraces, which present steep sea-worn fronts towards the Atlantic, as shewn in the annexed section, Fig. 20. Each of these terraces was in succession the bottom of a shallow sea, by whose successive elevations,

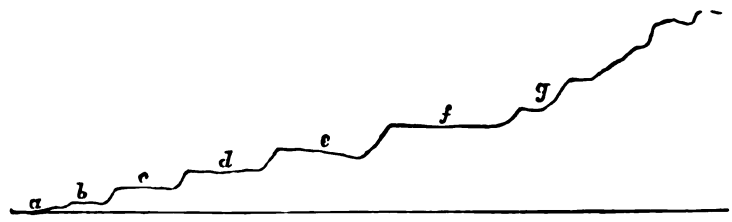


Fig. 20.

a, Atlantic; *b*, present sea border; *c*, 1st terrace, 250 ft.; *d*, 2nd terrace, 330 ft.; *e*, 3rd terrace, 580 ft., often lowering westwards and with marshy tracts; *f*, 4th terrace, 1200 ft.; *g*, slopes of the Andes.

after a long interval of repose, the present features were acquired—a conclusion entirely in harmony with the hypothesis regarding the elevation of the Pampean plains. In the wide sea thus supposed to exist, the western cordilleras and Fuegian mountains must have formed a series of scattered islands with rocky crests. There is good reason to believe that the southern portion of the continent is still steadily rising at the rate of several feet in a century; just as the N. of Europe and Asia, and most probably also Arctic America, are undergoing a gradual elevation. The whole of this gravel region of Patagonia is one of the most bleak and uninhospitable countries on the face of the earth; yet are some of the native tribes a tall race of men, and noted for their skill in horsemanship and the use of arms.

MAP VII.—PHYSICAL MAP OF THE BRITISH ISLES.

45.—GREAT BRITAIN consists of two parts essentially different in physical aspect and geological structure. Scotland, the northern part, is mountainous, without plains, and her rocks are of the older types. England, the southern part, has extensive plains and few mountains, while the rocks belong in a great measure to the younger formations. The boundary between them is formed by the Solway Frith, the river Liddell, the Lauriston and Cheviot hills, an imaginary line from near Cheviot top at their E. end to a point upon the Tweed at Carham between Kelso and Coldstream, in lon. 2° 18′ W., and thence by the Tweed to its mouth in the German Ocean. At the junction of the Lauriston and Cheviot hills in lon. 2° 35′ W., the hill-ranges of the two countries coalesce in Peel Fell, on opposite sides of which the North-Tyne, Liddell, and Jed rivers have their origin. Here a chain of hills is given off which extends due S. through Northumberland, Cumberland, Lancashire, and Yorkshire, to the S.W. of Derby. It forms the water-shed of the northern half of the country, and is a continuously high chain throughout, except at two points, of which one is between the head waters of the Ribble and Aire, where the Liverpool and Leeds canal crosses, elevation 500 ft.; and the other on the line of the old Roman wall between Carlisle and Newcastle, traversed by the railway, elevation 445 ft. The range does not attain any considerable height till it reaches Geltsdale forest, S. of which it has its culminating point in Crossfell, 2901 ft. high. Thence it ranges S. by Stainmoor forest where, in the western moorlands of Yorkshire, it exhibits the lofty summits of Whernside (W.), 2414 ft.; Ingleborough, 2361 ft.; Pen-y-gent, 2270 ft.; Whernside (E.), 2263 ft.; and proceeding still to the S. between Lancashire and Yorkshire enters Derbyshire and Staffordshire, forming the northern moorlands of

the latter, the "high peak" district of the former, and the wild tracts between Stockport and Derby, where the chain is 22 miles wide. It finally subsides about the centre of England, on the banks of the Trent, which, winding round its southern termination, turns from S.E. to N.E. in its course to join the Humber. At this end the highest summits are Great Axe hill, 1751 ft., and Weaver hill, 1154 ft. The chain has various local names, and the whole is usually designated as the "backbone" or "Pennine chain" of England, the latter name given by the Roman colonists from analogy with the Alps (Art. 13), or suggested by the native names containing the syllable Pen.

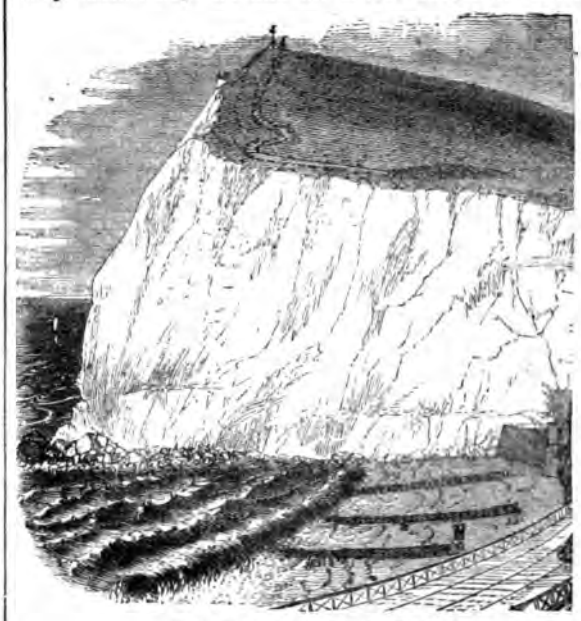
The Pennine chain gives origin to many rivers, the Tyne and Tees rising in Crossfell, the Ouse and Humber and their tributaries, the Trent, Ribble, and Eden; those descending eastwards having the longest courses, the more abrupt slopes being towards the west.

Closely connected with this chain by the high ground near Shap, but separated from it N. and S. of this by the narrow valleys of the Eden and Lune, there is a group of mountains covering a great part of Westmoreland, S.W. Cumberland, and N.W. Lancashire—these are the Lake Mountains or Cumbrian group; they are rugged and picturesque, and present the highest summits in England, as Scawfell Pike, 3166 ft; Scawfell, 3100 ft.; Helvellyn, 3055 ft.; Skiddaw, 3022 ft.; Bowfell, 2911 ft.; and others scarcely less elevated. The mountains of Wales or Cumbrian group have a general trend to the S.W. The range of Snowdonia in the north is the highest in the principality. Here Snowdon reaches a height of 3571 ft., which is greater than



SNOWDON.

that of any other mountain in S. Britain. The other principal heights are Caern-y-David, 3426 ft.; Cader Idris, 2914 ft.; Arran-Fowdy, 2970 ft.; Arrenig, 2808 ft.; Plinlimmon, 2463 ft.; Radnor Forest, 2163 ft.; Black Hills in the S., 2859 ft.; Van or the Beacons, 2394 ft.; Precelly Top in Pembroke, 1754 ft. Among these hills the Conway, Clwyd, Dee, Severn, Wye, Usk, Taff, and many smaller streams have their origin. Lower hill ranges traverse the border counties with a general direction N. and S. The principal of these are the Clee and Malvern hills, respectively 1805 and 1444 ft. in greatest height; the Lickey hill, the Clent hills, and the Wrekin (1320 ft.), are outliers in the great plain. In passing eastwards from the borders of Wales successive ranges of low hills are crossed, presenting their scarped sides to the west, sloping more gently east, and affecting one general direction from S.W. to N.E. These emanate from Salisbury plain as a centre, an elevated tract of an elliptic form, in the north of Hampshire, which has a general height of 500 to 600 ft. The ranges of the Chiltern hills and E. Anglian heights pass off to the N.E., and declining from 800 and 900 ft. to 300, terminate on the German Ocean at the Wash; the Cotswold hills (1134 ft.) of Gloucestershire, beyond the valley of the Avon, stretch northward, with a parallel range or outlier in Edge-hill (826 ft.). Eastwards and S. eastwards the north and south Downs extend from the same centre to the sea coast, where they terminate, the one on Dover Strait in cliffs



SHAKESPEARE CLIFF, DOVER.

350 ft. high, and the other in Beachy Head, the highest headland of England, 564 ft. in height. Between them lies the long level tract called the forest of the Weald, occupying portions of Surrey, Sussex, and Kent. The S. Downs do not wholly merge in Salisbury plain; a ridge extends W. to the Axe, where it ends in Pillesden Down 934 ft. high. The highest point in these eastern ranges, and of all the chalk hills in England, is Inkpen Beacon in the N. Downs near Salisbury plain; height 1011 ft. The long south-western extension of England is due to a narrow but high ridge of hard rocks, called the Dartmoor forest range, which extends through Devon and Cornwall to the Land's End, and has a general elevation of 1000 to 1200 ft.; highest

point, Cawsand Beacon, 1792 ft. A cross ridge and a high coast line, on which Brown Willy reaches 1368 ft., connect this range with the Exmoor group on the Bristol Channel, in which the Beacon reaches 1668 ft. Northward on the same coast, but having an axial direction at right angles to that of the Dartmoor range, there are the Quantock and Mendip hills, the greatest elevation of the former being 1428 ft., and of the latter 1100 ft.

46. Plains.—Between the Pennine chain and the Cumbrian group on one side, and the Cambrian group on the other, a wide level plain, called the Central plain, occupies the Midland counties from Liverpool to the range of the Chilterns. Bending round the southern termination of the Pennine chain, this plain becomes confluent with another, called the Yorkshire plain, which stretches N. to the mouth of the Tees, bounded westwards by the Pennine chain, which sends down into it many long gradually declining ridges, dividing the various river basins, with a height in their western parts of 1000 to 1300 ft., and eastwards separated from the ocean by the moors and wolds of York and Lincoln, whose highest point is 1485 ft. The eastern plain occupies the large tract of the eastern counties lying between the north Downs on the south, the Chiltern and east Anglian range on the west, and the German Ocean on the east and north. The plain of the Weald has been noticed already, and there are level tracts in other districts of the country; but their extent is too limited to entitle them to special mention. The significance of these various features, especially in their relation to each other, will be better understood when we come to consider their connection with the geological structure of the country.

Scotland.

47.—The hill ranges of the southern counties are connected with the Pennine chain of England at Peel Fell. A low ridge extending thence N.W. between the head waters of the Jed, Teviot, and Ettrick on one side, and those of the Liddell, Esk, and feeders of the Annan on the other, rises into high groups and mountain-knots about the sources of the Tweed, Clyde, Annan, and Moffat rivers, Queensberry hill, 2285 ft., being the point of bifurcation near the summit level of the Caledonian railway. From this centre a high range stretches far down into Peebles to the south of the upper Tweed, another northwards on the north side, chiefly under the name of the Pentlands, of which Arthur's Seat, 822 ft., is an outlier, and the Muirfoot and Lammermuir hills eastern dependencies. From the same centre the Lowthers and Lead-hills, of which the Tinto range ending at Carstairs, and a range running S.W. between Ayr and Kirkcudbright, are offsets, pass to the N.W. These and their continuations in the Haughshaw and Cathkin hills form a great watershed between Dumfries and Ayr on one side, and Lanark on the other. At the village of St. Johnstone, 12 miles S.W. of Glasgow, the range drops into the valley of the Ayr railway, which divides it here from the coast range. The highest on the W. side are Lowther hill, 2403 ft.; Black Craig, 2298 ft., and several others very little less. On the E. side, Hartfell, 2651 ft., the loftiest in the S. of Scotland; Blackwood Scar (Peebles), 2136 ft.; Tinto, 2200 ft.; Pentlands, 1900 ft.; Lammermuir, 1750 ft.; Muirfoot, 1450 ft. In connection with these may be named Salisbury Crags, 547 ft.; Edinburgh Castle rock, 383 ft.; Calton Hill, 347 ft.—These various ranges form the southern Highlands, and are distinguished from those of the north by their rounded forms and smooth outlines; they are without crags and rocky crests, and afford pasture-ground to their summits. The Cheviots are of the same character.

North of the northward terminations of these ranges, and dividing them from the mountain districts of the north, there is a broad zone of comparatively level land stretching from sea to sea between the Friths of Clyde and Forth. Here in a trough of unknown depth all the coal of Scotland has been deposited. These coal tracts are bounded on the N.W. from sea to sea between Ardrossan and Montrose by a well-marked range of hills so nearly continuous with one another as to be separated only by the channels of the Clyde, Blane, Forth, and Tay. The several sections thus formed are, the Coast range, highest point, Misty Law near Largs, 1751 ft.; the Lennox hills (Kilpatrick and Campsie), elevation 1400 ft. and 1800 ft.; Ochill hills, 2366 ft.; Sidlaw hills, 1700 ft. To the west of the last the valley of Strathmore, in Forfar and Perth, elevation 200 ft., and its continuation in the level tracts of Stirlingshire to the foot of Lochlomond, divide the Highlands from the Lowlands. The first or Highland section is again divided into two parts by the Great Glen, whose scenery is so justly celebrated for its variety and magnificence. It extends from the Moray Frith to



FINGAL'S CAVE, STAFFA.

Loch Linnhe, S. of Fort-William, has high bounding ridges, a maximum elevation of 94 ft., and shews no rock *in situ*—only rolled masses and heaps of shingle, and has plainly been, in a former state of the surface, a narrow channel connecting the two seas. By far the greater part of both divisions is covered with a vast assemblage of mountains, in some places disposed in groups, in others in ranges having a certain limited continuity, but in no sense arranged with reference to one central dominant ridge or axis. Instead of being connected together by a series of high ridges or cols, giving continuity to the mountains, and forming elevated passes from valley to valley, the mountains are cut down deeply on both sides, and a free and comparatively low passage across is opened up. The mountains do not, therefore, form a chain in the proper sense of the term. The nearest approach to it, however, is seen in the range of heights reaching from the Glencoe group to the north end of the Cairngorm group; and this range we may, in conformity with the common practice, designate the Grampians. The heights on the west side of the Great Glen affect a general parallelism to this range, and are continued S.W. into Mull; over the counties to the N.W. no true continuity can be traced; the heights decline toward the N.E.; and north-east Sutherland and Caithness are comparatively level. East of the Great Glen the line of heights is continued through Jura and Islay on one side, through Cantire and to the banks of the Clyde on the other. The rocks which drop into the sea at the extremity of Cantire are resumed on the opposite coast of Antrim, in the same relative position, under the same aspect and mineral character, with the same dip and strike, and are continued through the north-western counties as far as the northern shores of Galway bay. Now the rocks forming the Scottish Highlands are of the same mineral type as those of Scandinavia, and have a strong resemblance to them in the particulars just stated. Thus the great irregular and broken zone, from the White sea to Galway bay, is of one mineral type.

IRELAND.

48.—Ireland may be described in a general way as having a level and low interior, and an elevated border all round towards its four seas. The highest mountain group is at the extreme S.W. in the county of Kerry, and from this as a centre ranges of hills stretch along the eastern and western coasts; the hills are in isolated groups rather than connected chains, and the central plain is broken by short detached ranges less elevated than those upon the coast. The latter, from the extremity of Kerry to the S. side of Dublin bay, are nearly continuous. Interrupted for a space in N. Dublin and S. Louth they rise again, and high groups are found near the sea from N. Louth to the northern extremity of Antrim. In this county, through an extent of 50 miles, the lofty ranges pressing close upon the shore form, in their high mural precipices of white chalk and black basalt, with salient angles and re-entering bays, the finest piece of coast scenery in the United Kingdom. On the opposite side the continuity of high ground is broken by the low sea coast of Clare, from the

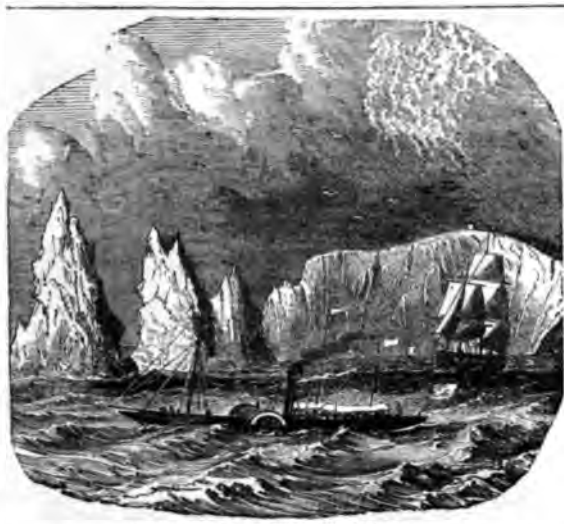


CARRICK-A-REDE, ANTRIM.

Shannon to Galway; to the N. and N.E. of this, as far as Innishowen head on Lough Foyle, the coast is mountainous, the ranges being prolongations of those of the Scottish Highlands (Art. 47). The central plain is unbroken from Dublin to Galway, and does not rise above 250 ft. From Lough Neagh to the mouth of the Shannon it is almost equally continuous, spreads out in all directions into the spaces between the coast ranges, and runs in among their inland branches and spurs like bays and gulfs upon an indented coast. The level seldom passes 500 ft. The isolated groups which rise from the plain as islands in the sea are Slieve Bloom, 1691 ft.; Keeper, 2265; Mt. Leinster and Blackstairs, 2064 ft. Of the coast ranges the heights are Carntoul, highest of Macgillicuddy Reeks, 3404 ft.; Galtees, 3008 ft.; Knockmeledown, 2700 ft.; Lugnaquilla (Wicklow mts.), 3039 ft.; Slieve Donard (Morne mts.), 2796 ft.; Trostan (Aura mts., Antrim), 1820 ft.; Muilrea, Nephin, Croagh Patrick (Connemara group), 2680 ft., 2530 ft., and 2370 ft. respectively. Errigal and Muckish (Donegal mts.), 2460 ft. and 2190 ft.; Slieve Snacht, Innishowen, 2019 ft.

49. Lesser Islands.—Isle of Man.—The Isle of Man is traversed in its greatest length by a range of hills reaching a maximum elevation in Sneafell of 2004 ft. Ridges sent off laterally run toward a coast-border of little elevation, and dividing the courses of the short streams. The northern promontory is a low tract of flat land without rock *in situ*, being occupied by beds of tertiary origin and recent alluvia.

Isle of Wight.—A high chalk ridge runs through the middle of the island from Culver cliff on the E. to the Needles on the W.—highest point on St. Catharine Downs, 830 ft. North of this ridge the island slopes gently to the Solent Frith; south



THE NEEDLES, ISLE OF WIGHT.

of it the surface is broken into irregular platforms with terraced sides, giving effects of the most picturesque character. The under-cliff district, remarkable for its warm, sheltered situation, is due to an enormous subsidence; and the island in every part bears the evidence of a great convulsion subsequent to the formation of the newest beds.

The Long Island.—This singular group comprises the Lewis, Harris, N. and S. Uist, Benbecula, and many others. Several of them are connected at low water, the narrow channels between being then passable. The present aspects have been brought about by a general subsidence, which is believed to be still going on. The name is thus very expressive. Harris and S. Uist have mountains reaching 3000 ft. and 2760 ft.; the others are comparatively low.

Skye, Mull, &c.—These, with dependent smaller isles, are often called the Inner Hebrides. Skye has a group of high mountains in the S.E. called the Coolin hills, the most wild and picturesque in the British Isles, or perhaps in Europe. The eastern shore is bold and lofty; the rest of the island consists of bleak moorlands little elevated above the sea level. Highest point of the Coolin hills, Scuir-na-Gilean, 3200 ft. Mull is a mass of mountains; highest point Ben More, 3178 ft.

Arran has a group of most picturesque mountains in its north part, to which the Coolins only in Britain are superior; highest, Goatfell, 2865 ft. The rest of the island is a rolling broken plateau of considerable height, and covered with moors; the maritime border has wondrous beauty. **Bute** is a low and fertile island. **Ailsa** is a single cone of igneous rock rising out of deep water in the middle of the Frith of Clyde, elevation 1114 ft.

Orkney and Shetland.—These islands present steep rocky fronts to the surges of the Atlantic, and have gradual slopes eastward. They consist mainly of irregular rocky moorlands little elevated above the sea; the highest point being in Mainland of Orkney, and no more than 1600 ft. in height.

50. Coast Outlines.—The coast outlines are remarkably contrasted on the E. and W. sides of the British Isles; on the east they are little broken, partly from the more uniform hardness of the rocks, but mainly from the lesser force of the waves in the narrow and shallow German Ocean, than in the Atlantic under the unbridled fury of the western storms. The depth of water along the shores, as exhibited on our map by the two lines of soundings, stands in interesting relations to the form of coast line, and we shall see further on how these same outlines are related to geological structure.

MAPS VIII. and IX.—VARIOUS SECTIONS,—referred to in description of MAPS II. to VI. and in XV.

MAPS X. and XI.—DISTRIBUTION OF HEAT.

51. General Conditions.—The causes which determine the distribution of heat, and give us our actual climates, are various and complex. If the Earth's surface were uniformly covered with water, or if it were a continuous mass of level land, the lines of equal temperature would be everywhere parallel to the equator. But the floor of the atmosphere varies everywhere—part of it rests on a fluid base, part on a continental. The oceanic bases are of different forms and in different positions, and the continental masses vary in their physical conditions: some covered with vegetation, as Europe and America; others, as large tracts of Asia, Africa, and Australia, consisting of arid plains. There are besides hemispheres of "most land" and "most water," vast bodies of warm and cold water circulating in the oceans, and on the continents huge elevated masses in mountains and plateaux. The air itself retains very little of the Sun's heat which passes through it; its temperature is derived mainly from the Earth by radiation of its heat thus rendered more absorbable, and by constant contact with a surface so heated. Placed in this air, breathing it, moving in it, surrounded on all sides by it, man depends upon its changing conditions for his life, health, and comfort—not less essential is it to all animals and plants, the temperature of the ground affecting animals but little, and acting in a slight degree only on vegetable life. The constitution of the atmosphere complicates greatly the effects due to the surface on which it rests. The aqueous vapour which it contains has a different relation to heat from the air itself. While both are highly elastic and capable of immense dilatation, the one incapable of being reduced to a liquid by any degree of cold or pressure yet known, the other liquefying readily

by natural means. The extreme mobility of the air causes a change of condition, originating in a particular tract, to be propagated far and wide, interfering with and masking the effects due to causes there operating. These considerations shew that there must be great difficulty in assigning the true causes of changes, and in arriving at general laws regarding them. It is only of late years that some such laws have been deduced mainly by the researches of Humboldt, and a comparison of the combined system of observations established through his influence by the principal maritime nations of the world.

52. Isothermal Lines.—The lines upon a map or globe, which graphically represent climate, are isothermal lines, or lines of equal warmth, whose position has a certain proximate dependence upon that of the equator of the Earth, and a certain rough resemblance to parallels of latitude. Of these there are several systems—the yearly isothermals, which represent the *mean* annual-temperature of the places through which they pass. These, however, do not express with precision the *actual* climate of a place, since an *excessive* climate, with seasons strongly contrasted, might give the same mean as an *insular* climate in which the seasons are of an equable character. In fact, the details of which the means consist must be known in order to express the actual climate. Isothēral and isocheimōnal lines, or lines of equal summer and equal winter temperatures, more nearly represent the climates of the places through which they pass. The monthly isothermals accomplish this object still more perfectly, and are in fact the true climate lines of the globe; monthly temperatures deduced from daily observations, are dependent on atmospheric affections, varying from day to day with the direction of the wind, the quantity of rain, and the state of the sky as to cloud and sunshine. We have made the nearest approach to this that was possible for us, by grouping the months in terms of three each upon four maps, Plates X. and XI., thus placing the *seasons* in direct comparison at different places, and enabling the student of these maps to realize more easily the main conditions of life than he could do from the monthly isothermals. Each line is constructed to represent the mean temperature of the three months in degrees of Fahrenheit. There being nothing else upon the map, there is no possibility of confusion, and a careful study of these lines will convey more information than a lengthened description. It is thus unnecessary to do more than indicate a few points of interest.—Most of the lines, at all seasons, depart widely from the position of parallels of latitude. The isotherms of 59° and 68° in spring, that of 68° in winter of the northern hemisphere, and that of 50° in winter of the southern hemisphere, which passes through Melbourne and Monte Video, are perhaps the only ones which approach such a position. The inflections of the others under different meridians, shew how influential are other causes than distance from the equator. The inflections in the northern hemisphere in winter are the most remarkable of any. Of these striking examples are seen in the isotherms of 32°, 14°, and 5°; their steep ascent and descent on either side of an axial line running up the Atlantic N.E., manifestly point to a great source of heat in winter in that ocean, in virtue of which Bear Island, in lat. 75°, has a winter temperature like that of Quebec in lat. 46°, and the mouth of the Ural in lat. 47°. The descent of these lines so far into the heart of both continents, and their ascent on either side, shew in a striking manner the contrasted winter temperatures of the land and sea; the higher latitude reached on the west coast than on the east, the superior warmth of the former. At the other seasons, especially in summer, the lines are all flatter and the contrasts less. The inflections at all seasons shew the irregular decrease of temperature towards the poles.

53. Normal Temperature—Thermic Anomaly.—The approach to a mean decrease is more remarkable in some parts and at certain seasons than at others. Such a mean decrease, or, which is the same thing, the temperature due to the latitude, has been determined with tolerable accuracy by the researches of M. Dové. This is the *normal temperature*, or that which a place would have, if its temperature, now variously distributed, was distributed uniformly. The *thermic anomaly* is the difference between the normal and actual temperature. In North America, the thermic anomaly varies in different parts from 7° to 11° F., that is, the winters are by so much colder than they ought to be for the latitude; but the summers have not a much greater degree of warmth, only 4° or 5° F. in the northern part of the United States. If the globe be supposed to be divided into two unequal parts by the tropic of Cancer, the land masses north of it have on their *western* coasts a temperature in excess of the normal temperature, those on the south of it a temperature on their *eastern* coasts in excess of the normal; while the *east* coasts of the northern masses, and the *west* coasts of the southern masses are colder than the normal. * In the hearts of the continents, the usual rule is, that the temperature of winter is below the normal, and that of summer above it.

54. Temperature of Whole Earth.—That the temperature of the whole Earth is not the same from month to month will be obvious, if we consider that its variously constituted surface is differently placed to the Sun in the different months. The southern hemisphere of water affects the temperature of the air differently from the northern hemisphere of land. The mild winter of the southern hemisphere, which has "a sea climate" or "insular" climate, *plus* the hot summer of the northern hemisphere, which has a "continental" climate, give a higher sum of temperature than the cool summer of the southern, *plus* the cold winter of the northern hemisphere. In fact, the temperature taken generally increases from January (summer in the south) to July (summer in the north) by about 8° F., which has been determined thus:—The mean temperatures for the two hemispheres are, northern, July 70°·9, January, 48°·9, mean 59°·9; southern, January 59°·9, July 53°·6, mean 56°·5; whole Earth, July $(70°·9 + 53°·6) \div 2 = 62°·25$, January $(48°·9 + 59°·5) \div 2 = 54°·2$; difference $62°·25 - 54°·2 = 8°·05$ F. for

* Sir J. Herschel, *Phys. Geog.*, Art. 252. These contrasts are caused by the direction of the ocean currents and trade winds, q.v.

the whole Earth, and mean for the whole Earth 58°·225 F. The cause above assigned would be more influential but for the greater nearness of the Earth to the Sun in the month of January.

The Sun crosses the Line on March 21 and September 21, yet the maxima temperatures do not occur then, but later, in April and November, the effect accumulating with time; the minima are in July and December. The *mean* temperature of the whole terrestrial equator is calculated at 79°·8 F., but the warmest parallel is that of 10° N.; and there May is the warmest month. From lat. 40° N. to the pole, July is the warmest month; in lat. 30° N., August is the warmest; in lat. 20° N., the two are equal. The temperature of the pole in July is 30°·6, in January −26°·6, mean 2° F. In July, the equator is 48° warmer than the pole, in January 106° warmer. These values for the polar temperature are estimates merely, derived from various considerations, as no one has ever reached nearer the pole than about 500 miles distance.—The actual pole may not average less than 15° F.

From the equator to lat. 40° S., the southern hemisphere is colder than the northern; but it has not yet been made out that the rule holds for higher latitudes, though many facts point in this direction; such as the terrible severity of the climate about Cape Horn in the latitude of Edinburgh, and the descent of snow during most of the year to the sea-level in S. Shetland, S. Georgia, and Cockburn island, which lie in a latitude between that of the Orkneys and the mouth of the Tees; and whose vegetation consists of one grass, two herbaceous plants, and the rest mosses and lichens only.

55. Range of Temperature.—The limits of the fluctuation of temperature constitute what is called Range, and would be graphically expressed by the directions of the isotheral and isocheimonal lines for any place or parallel of latitude. Range is an essential element in the character of a climate, especially as regards its relations to the human constitution. Insular climates have a small range, continental large. Even in January we can pass from the Shetland isles to the English channel without changing the temperature. West of this, in Cornwall and the S. of Ireland, the temperature is higher in winter, and here therefore is the best winter residence for invalids; the difference of the seasons is reduced to a minimum. At Dublin, the mean summer and winter temperatures are 59°·8 F. and 41° F., range 18°·8; at Yakutsk, in the same latitude, the range reaches the fearful amount of 106° F., the extreme temperatures being 62°·2 in July, and −43°·3 in January. In the Friendly isles, summer and winter differ only by 2° F. Places of like range have been connected by a system of lines called Range Lines. These intersect the western coasts of the continents at higher northern latitudes than the eastern, for the reason already assigned.

56. Spaces of Greatest Heat and Cold—Poles.—From causes which in many cases are very obscure, certain tracts of the Earth's surface of limited extent have temperatures greatly in excess or deficiency of others adjoining. Thus the hottest part of the globe is a tract comprehending E. Africa and Arabia, whose limits vary beyond these boundaries in spring and summer, as marked on our map, and where the temperature ranges from 86° to 95° F., and in spots peculiarly situated reaches 100°, and even 130°. Thus Dadur, near the Indus, at the entrance of the Bolan Pass, has often a temperature of 130° F., owing doubtless to the station lying in a hollow among white hills. A thermometer in the shade at Mourzuk in Fezzan often shews 132° F., which Humboldt explains by supposing that the air is full of hot particles of sand, which act as centres of radiation. In S. Russia, temperatures of 100° to 110° are sometimes noted. At Frankfort-on-the-Maine, we once experienced in July a temperature of 100° F. in the shade, in a place quite screened from solar influence. —The coldest tracts on the globe are defined by the inflections of our winter isothermals in the Arctic regions. They lie on opposite sides of the north pole, which is warmer than either. The Siberian is colder than the American region, the one being 15° and the other 13° below the normal temperature. The small space of maximum cold within this tract, or, as it is called, the focus or pole of cold, is displaced from the Asiatic side in January to the American in July, and returns again to Asia in the second half of the year. It thus oscillates round a mean position. The American focus is in lat. 65° N., lon. 96° W., the Asiatic in lat. 61° N., lon. 122° E.; the cold of this latter is probably due to the lofty mountains to the south (Art. 22); that of the former to the constant currents of icy water out of Behring's Strait. Occasionally in other places even lower temperatures are experienced than any recorded within these tracts; −120° F. has been noticed in Siberia, and −70° in the Arctic Ocean. These extreme temperatures are not of course recorded with quicksilver, which freezes at −37°·9 F., but with pure spirit of wine, which has never been frozen by any degree of cold.

MAP XII.—CONSTANT, PERIODIC, AND VARIABLE WINDS.

57. Trade Winds.—The range of the isotherms along the surface of the globe shews us that there is at all seasons of the year a broad zone in the equatorial regions having a temperature not less than 77° F. The limits of this zone vary with the Sun's declination (Art. 54), oscillating backwards and forwards obedient to his movements. The air in contact with it is greatly heated at all times, is rarefied and becomes lighter; and so is constantly rising into the higher regions of the atmosphere, and flowing outwards north and south toward the poles. To restore the equilibrium the cold air of the polar regions flows in at a low level towards the equator; just as we see, when we open the door of a

heated room, that the flame of a taper is blown outwards at the top and inwards below. A difference of temperature establishes these two great primary currents, on which depend the Trades, and other phenomena of the winds. Now, the entire mass of atmosphere, reaching to a distance above the Earth's surface equal to one-eightieth of its radius, is constrained to move bodily with the Earth, partaking of its movement of rotation, which is greatest at the equator, and gradually diminishes to nothing at the poles. Thus, a point on the equator moves at the rate of 17 miles per minute, and one in the latitude of 60° at 8½ miles per minute; and in the higher regions of the atmosphere, the rates will be a little greater. Within the polar circles, then, the air has a relatively small velocity of rotation eastwards, and being transferred towards the tropics in the direction of a meridian, is moving eastwards much more slowly than bodies upon the Earth's surface, and will lag behind, or drag upon them, with a westerly tendency. These, therefore, strike against it toward the east at a velocity equal to the difference between their own rate of rotation and that of the air over them; and in virtue of this compound motion, the southerly tendency combined with the westerly, the direction of the wind is *toward* the south-west or *from* the north-east on the north side of the equator, and *toward* the north-west or *from* the south-east on the south side. The reason why the tendency to these directions does not manifest itself farther from the equator than about lat. 39° to 30° probably is, that the polar currents are at first at a considerable height in the atmosphere, and do not descend to the surface till the *indraught*, a little beyond the outer limits of the torrid zone, begins to act very strongly. The rarefaction of air about the equator occasions a diminished pressure and great indraught; there is a diminished pressure also towards the poles—amounting in the Antarctic Ocean to fully one inch—due to the partial vacuum produced there, as being the apices or central parts of the great vortex in which the atmosphere is revolving; the centrifugal force of the revolution tending continually to cause a partial withdrawal of the air from those parts of the rapidly whirling mass. Neither cause acts towards the tropics, and so the air has there a greater, or about the normal, pressure.

The N.E. trade extends in the open Atlantic, as a rule, from lat. 9° N. to 30° N., but has been met with as far N. as lat. 39° N.; in the Pacific, from 9° N. to 26° N. The S.E. trade in the Atlantic ranges from 4° N. to 22° S.; and in the Pacific from 4° N. to 23½° S.; but the limits advance a little both ways with the advance of the sun into each hemisphere. The oscillations for the seasons are shewn upon two small separate maps. The S. or equatorial limit of the N.E. trade shifts with the seasons from 5° 15′ N. to 11° N., and the N. limit of the S.E. trade from 2° N. to 3° 15′ N., so that the dividing or medial line is always N. of the equator.

58. Monsoons.—The other great intertropical ocean is so peculiarly placed in relation to land masses, that the constant winds which ought to blow there, as in the Atlantic and Pacific oceans, are changed in character by the local conditions; and the wind which would otherwise be constant is constrained to become periodic—the trade wind passes into a monsoon. The monsoon is a periodical wind which blows up and down the Indian Ocean alternately for six months in the year. It is generated by differences of temperature in the atmosphere. When the Sun crosses the equinoctial (March 21), the mass of atmosphere resting on S. Asia begins gradually to acquire a high temperature from the heated surface of the Earth; the air over this ascends, the barometric pressure is reduced half-an-inch, and the cold air from the southern hemisphere, where it is winter, rushes in to supply its place, and continues to blow during the summer. This would produce a south wind; but as the moving body of air comes from a part of the globe where the axial motion is quicker, it tends to make the air amid which it comes move quicker towards the east, that is, instead of being a S. wind, this easterly tendency, combined with the northerly, produces a wind moving N.E., that is, a S.W. wind. Near the coasts, however, the direction is modified by the indraught of heated land. Thus, on the coast of S.E. Africa, the monsoon is a S.E. wind; on the W. coast of Australia, S.S.W. and W.N.W.; on the Malabar coast of India it is a S.W. wind; on the Coromandel coast a S.E. wind; all along the S. coast of China, and far into the interior, it is a S.W. wind, and the arrangements of the Chinese farmer are made in expectation of its punctual arrival. The change to an opposite direction takes place about the autumnal equinox, when the Sun re-crosses the Line; the monsoon then becomes a N.E. wind, or true trade, during the winter of Asia, and will manifestly be a much drier wind than that from the S. The approaching change, or "shifting of the monsoon," is indicated high in the atmosphere by an opposite "carry" of the clouds many days before the wind changes on the surface. When, at length, the two currents intermingle, violent storms, and often hurricanes, are produced. These occur of even greater violence at the change in spring; the equilibrium of the atmosphere is disturbed far and wide at both seasons, the disturbance being intimately related to the "equinoctial gales" of the temperate zone. The navigation of the China Sea and Indian Ocean is arranged with reference to the monsoon. The fleets homeward bound take their departure when the storms are over, and the N.E. monsoon fairly established. Thus, vessels leave the Cape for India and China in April, and in October start on their homeward course.—Similar monsoons prevail, though of more limited extent and less regular, on the W. coast of Central America, S.E. coast of Brazil, and S.W. coast of Africa; the latter being of the utmost benefit to navigation in carrying vessels across the "Doldrums," or zone of equatorial calms. The word Monsoon is said to be a corruption of the Arabic word *Mansim*, a set time or season.

59. Variable Winds.—The winds of extratropical regions are variable, "whirling about continually;" averages of their directions shew that they have a greater tendency to blow towards the poles than from the poles, and that of the former by far the

most prevalent is a wind from S.W. or W.S.W. The reason is obvious. The equatorial return current, or anti-trade, flowing N. and S., has a higher rotatory velocity than the air amid which it is being constantly transferred; hence it does not keep on the same meridian, but inclines continually more and more to the eastward, and when it descends toward the surface outside the tropics, as yet little affected by friction, owing to its height, it has a powerful tendency eastwards; this combined with its northern tendency produces a wind moving N.E., that is, a S.W. wind. This is the origin of the prevailing westerly winds, and of the gales and storms from the S. and W., which far surpass those from any other point of the compass. The local varying winds of temperate regions seem all to occur in a low stratum of air which moves slower, owing to friction and impulses on the earth, than the air above, and flows to the poles to supply the vacuum caused by the vortex due to the centrifugal force of its revolution. Over this lowest stratum the polar current flows toward the equator as a return current. Retarded by mixture with the lower current, by coming against mountain ridges, and by being occasionally dashed to the Earth's surface, it yet still receives from above fresh accessions of rotatory motion in advance of the Earth's axial motion, the upper equatorial current bringing such with it; this middle current thus moves faster than the lower, and has more centrifugal force tending to make it move towards the equator; for want of such centrifugal force the lower current moves towards the regions of diminished pressure in the centre of the great vortex, that is, towards the poles. —Prof. J. Thomson in *Brit. Assoc. Report, 1857.* It was found by Mr. Glaisher in all his balloon ascents, that when a wind was blowing at the surface, the velocity was much greater aloft than below.

The prevailing wind and that which brings the heaviest storms in the southern hemisphere is for a like cause the north-west wind. The primary tendency of the equatorial return current is toward the south, while the excess of rotatory velocity gives an easterly tendency; these two produce a N.W. wind. The currents of the two trades meeting towards the equator neutralize one another, and produce a region of calms; from this the air ascends to begin a new circuit. But as the thermal equator is many degrees north of the geographical equator, so it happens that the south-east trade crosses the equator into north latitude in our summer, to return again during the summer of the southern hemisphere. The zone of calms is 4° to 5° broad, stretching across both oceans nearly parallel to the equator. It is a cloudy region, of low barometric pressure, with daily heavy rains, and frequent severe thunderstorms.

The prevailing south-westerly winds of the northern hemisphere manifest their force and constancy in producing frequent storms in the North Atlantic, and in retarding the passages of ships from Europe to the United States, and in accelerating the homeward vogage. Professor Ehrenberg has ascertained that the red dust which falls on ships in the Atlantic, along the south of Europe, and as far north as the Tyrol, consists of minute infusorial animalcules and other organisms belonging to equatorial America, borne up with the ascending equatorial air, and wafted aloft on the return current. This current reaches the British isles. While other winds are blowing at the surface, a current comes steadily from the south-west for several days at a great height; and when indicated by small roundish masses of cumuli, thin at the edges and touching one another at the circumferences, is accompanied by a very high barometer. Gradually descending, it mixes with the surface current; the cumuli are resolved into a thick background of cirri and cirro-strati; the barometer rapidly descends, and gales of wind, with heavy falls of rain, follow.

There are but two normal winds in the northern hemisphere, the south-west and north-east; the others are local or transition winds. The north-east polar current tends continually to bend round to the east, so as to become an east wind; and the south-west return current, as it advances north, tends more and more to assume a direction from due west. This seems to be the reason why, in the northern part of the temperate zone, the winds move round from south by west to north, and from north by east round to south. In the southern hemisphere the order of progress is the reverse. The effect is due to friction.

The land and sea breezes on the shores of tropical lands, alternating during the night and day, arise from the different relations to heat subsistent between land and water. In our own latitudes, in hot summer weather the same phenomena are observable on open coasts. Variable winds are referrible to many local causes—a rainfall in some adjoining tract will cause a wind towards it; the formation of cloud over a particular district liberates latent heat, and a rarefaction of air is produced, which gives rise to a breeze or gale according to the amount of heat liberated. The spring east winds of Great Britain are a branch of a great current setting S.W. towards the heated tracts of S. Europe, from a region of cold, and high barometric pressure, in Russia.—We do not as yet by any means understand all the causes of the variations and sudden changes which we experience; but we have entered now by means of our various combined observations, and the admirable telegraphic correspondence in regard to storm-warnings by the Meteorological Office, upon lines of enquiry which cannot fail to throw great light upon this most obscure and difficult subject. If the lines of equal barometric pressure all over the globe could be laid down like the monthly isothermals of Humboldt and Dové, we should have a nearly complete theory of winds and storms. "They would indeed furnish the key to all questions of meteorological enquiry." Such a system of lines has been proposed by Mr. Buchan of Edinburgh as a first approximation, and is given in three charts in his work on Meteorology. He has been the first to set forth such a scheme, and to face the extraordinary labour of working out all the reductions required upon a vast mass of observations. (See also *Trans. R.S.E.*, 1868.)

Many of the "variable" winds are yet of such

constant occurrence in particular tracts of country at certain seasons, that special names have been given them. The *Sirocco* of Africa blows off the hot deserts towards the N.; it crosses the Mediterranean in a broad belt traversed by the mail steamers, and reduces the passengers to a state of langour and listlessness, putting a stop to all enjoyment; it is grievously felt in Malta, Sicily, and S. Italy, and in the S. of Turkey, where it is called *Samiel;* and its effects are felt even as far north as the Alps and the Black and Caspian Seas. It blows often with much force, and carries along a great quantity of fine sand. —The *Harmattan* is another hot wind blowing from the Sahel out to sea between lat. 1° S. and 15° N. (Art. 29). The *Khamsin* is a hot wind of Egypt, which blows from the end of April till the middle of June, or 50 days.—The *Simoom* is a similar hot and suffocating wind of the Arabian and African deserts;



THE SIMOOM.

it often reaches the force of a tempest, and lasts from 6 to 24 hours.—The *Solano* of S.W. Spain is a hot, dusty S.E. wind of the summer season.—The *Mistral* of France is a violent and steady N.W. wind blowing upon a tract of low pressure over the Gulf of Lion and N.W. Italy.—The *Bora* is a similar cold and violent wind, which blows from the Alps upon the Gulf of Venice, and is probably the "Euroclydon" of St. Paul's voyage.—The *Etesian* winds are the N. winds of summer in S. Europe, blowing towards the heated surface of Africa; a more violent wind further E. is called a *Levanter.*—The *Pampero* of Buenos Ayres is a violent W. and N.W. wind of summer, which sweeps the pampas from the Andes to the ocean, ending in violent thunderstorms (Art. 44 *c.*) —The *Puna* of the west coast of equatorial America is a violent wind, thought to be an overflow from a region of high pressure in the S. Atlantic to one of low pressure in the N. Pacific. On descending from the cordilleras, it is the most arid wind known—under it a dead mule is speedily converted into a mummy, and the theatre of its action was chosen by the ancient Peruvians for the interment of their dead.

60. Hurricanes and Cyclones.—The hurricanes and cyclones of the American sea-board and Indian Ocean are thought by some to be due to a sudden descent of great bodies of the return current among the moving air of the Trade. This descent might be produced by several causes, a great rarefaction in a particular tract on the surface, or a heavy rainfall; the excess of velocity, especially if the transference be sudden and there be other currents at the surface, might give rise to most powerful movements, and that rapid whirling or vortex motion noticed in all the tropical hurricanes. A sudden transference *in latitude* might produce similar effects, owing to the different rates of rotation. It has also been supposed that these storms may originate in the impact of the polar current descending along the Rocky Mountains, and crossing thence over the United States, against the return current from the south-west. Various other theories have been framed to account for these singular and destructive storms. They originate east of the Lesser Antilles, and move first towards the north-west; beyond Florida they bend round and travel in a parabolic curve nearly in the direction of the Gulf Stream, and end near its great deflection, between the Bermudas and Halifax. While the centre of the cyclone, or mass of moving air, thus advances, its parts revolve about a vertical axis, so that the direction of the wind varies continually. There is a calm round the centre for many miles, and outside of this the wind blows with great fury, the velocity decreasing towards the circumference of the gyrating mass. The direction of the rotation in the northern hemisphere is contrary to the movement of the hands of a watch, so that on the S. side of the circle the wind blows from the west, on the east side from the south, and so on. In the southern hemisphere the direction is the reverse of this, being conformable to the motion of the hands of a watch. The knowledge which has of late years been diffused regarding cyclones, has been of the utmost use to navigation. From our diagrams it will be seen that the sailor can easily ascertain *the position of the centre,* in relation to his own place, by observing the direction of the wind, and the way in which it veers round; on this knowledge his measures are taken for the safety of his ship.

The path of the centre is usually a parabolic curve (see Map); the storm area is often 500 to 1500 miles wide, often 100 to 150 only; near the centre the pressure is often as low as 27 inches. If the centre be not very distant the wind will blow right towards it; but if the distance be considerable, and one stand with his back to the wind, the centre will be towards his left hand; that is, the wind will blow towards a point to the right of the centre. It is found, for example, that when the centre of one of the Atlantic storms that cross N.E. from the S.W. of Ireland is over Liverpool, the wind at London is a little W. of S., instead of being nearly S.E. or toward the centre. Hence, if the path of the centre and its

velocity be known, the direction at any port can be predicated. This rule holds for the northern hemisphere, and is that which is followed in steering a ship out of the course of the storm. The typhoons of the China sea travel from E.N.E. to W.S.W., and are probably due to an interference between the current of the S.W. monsoon and that of the N.E. trade of the Pacific; they are most severe in the hottest months of summer. The cyclones of India originate in the E. part of the bay of Bengal, and advance towards the mouth of the Ganges. The cyclones of the Indian Ocean S. of the equator travel W.S.W., turning to S. and S.E.; they have their origin in the region of calms dividing the two trades of the S. Indian Ocean, that is, the N. or N.W. wind which blows in the summer of the southern hemisphere off S.W. Asia and S.E. Africa, and the S.E. trade of the E. part of the Indian Ocean. (See Map.) There is great uncertainty here in regard to the position of the centre, and the safest course is to lie to till this can be found, or till the storm passes.

In ordinary storms in this country it is not so much lowness or a sudden fall of the barometer that indicates their approach, as a great difference of pressure at places not far removed from one another. A difference of 1 inch in 150 to 200 miles is sufficient to produce a storm of great violence. Such storm may rage at one place, while at the other it may be calm or only a light wind. The early morning and forenoon were quite calm at Glasgow, and the previous night had only occasional slight gusts from N.W., just audible in the chimney tops, while the "Royal Charter" was perishing in a terrible gale on the N. coast of Wales.

61. Velocity and Pressure.—The pressure of the wind on a given surface and velocity per hour have been determined by various observations and mechanical contrivances to which we cannot here advert; and these elements are so related that one being known the other can be approximately found. Thus, if P and V be the pressure and velocity, we have $P = V^2 \times \cdot 005$ and $V = \sqrt{(200 \times P)}$. A scale of velocity has been adopted for the sake of mutual understanding among observers, the numbers running from 0 to 6.

A calm,	0	P = 0		V = 0	
Light air, ...	(·5)	P = ·25	lb.,	V = 7·1	miles per hour.
Light breeze, ...	(1)	P = 1	lb.,	V = 14·1	,,
Gentle breeze,	(1·5)	P = 2·25	lbs.,	V = 21·2	,,
Moderate breeze,	(2)	P = 4	lbs.,	V = 28·3	,,
Fresh breeze, ...	(2·5)	P = 6·25	lbs.,	V = 35·4	,,
Strong breeze,	(3)	P = 9	lbs.,	V = 42·4	,,
Moderate gale,	(3·5)	P = 12·25	lbs.,	V = 49·5	,,
Fresh gale, ...	(4)	P = 16	lbs.,	V = 56·6	,,
Strong gale, ...	(4·5)	P = 20·25	lbs.,	V = 63·6	,,
Whole gale, ...	(5)	P = 25	lbs.,	V = 70·7	,,
Storm, ...	(5·5)	P = 30·25	lbs.,	V = 77·8	,,
Hurricane, ...	(6)	P = 36	lbs.,	V = 84·8	,,

A velocity of 100 miles per hour corresponds to about 50 lbs. pressure. The average of storms in this country is 20 to 30 miles per hour, and sometimes 54 to 75; but in our worst hurricanes occurring at rare intervals, 100 to 120. The tropical hurricanes reach 120 to 130 miles per hour. While the centre of the gyrating mass in a cyclone is advancing at the rate of 20, 30, and even 90 miles per hour, the rate with which the winds whirl spirally round upon the centre has been determined to be from 80 and 100 to 120 and 130 miles per hour; the indraught towards the centre or direct wind is seldom so much as this.

MAP XIII.—RAIN AND SNOW.

62. Rain.—The quantity of rainfall in different parts of the earth has, speaking generally, a direct ratio to heat; it is greatest in those regions where the evaporation is greatest; the zone of calms, a little north of the equator, is a region of constant precipitation. The great power of the solar rays causes a prodigious evaporation in this tract of ocean; the vapour thus formed, as well as that brought by the trade winds, which are of different temperatures and hold different quantities of vapour in solution, is borne upward by the ascending currents, and condensed into a cloud-ring, or broad stratum overhanging the belt of calms. A constant succession of fresh vapour supplied from below, and cooled aloft, must necessarily produce a constant precipitation; and this, combined with changes in the electric tension, causes also a continual succession of thunderstorms, which frequently occur above the upper surface of the ring.—The ascending currents cease towards evening as the Earth cools; the clouds then descend and are dissolved by the warm air, the Sun sets in a clear sky, and the nights are serene and cool.—Before mid-day the cloudy ring is again formed, and the cycle is renewed.

For the reason already given (Art. 54-57), this cloud-ring changes its position with the Sun's change of declination, oscillating from 5° S. to 15° N., and giving, therefore, to these latitudes two rainy seasons, the summer of each hemisphere. The change takes place at the equinox, when the Sun passes through the zenith; the rains, however, extend considerably beyond the above latitudes, chiefly in consequence of a lateral extension of the upper portion of the cloud-ring, partly due to the relief afforded by the condensation into rain, and partly to the effect of the upper return current. The average annual rainfall within the tropics varies greatly with local conditions. Where the trades blow regularly it is not great, because the vapour of the low current is constantly advancing into a warmer region and being dissolved, while the upper return current has discharged most of its vapour in the region of calms. The average is about 95 in., but in many places it is far above this. The coast of Senegambia has 189, Paramaribo 229, Maranhão 280, Doldrums of the Atlantic 225, Vera Cruz 183, Caraccas 155, Georgetown 100, St. Domingo 107, Pernambuco 106, Sincapore 97, Barbadoes 72 Rio de Janeiro

59, Bahamas 52. The greatest known rainfall in the world is on the Khasia mountains, 150 miles N. of the head of the bay of Bengal. They run E. and W., are very steep to the S., and have a height of 4000 to 5000 ft., with peaks about 6000 ft. They arrest the cloud-bearing current of the S.W. monsoon, and cause a deposition of the enormous amount of 540 inches of rain, and sometimes 610 inches, 500 inches of which fall in 7 months. At 20 miles N. the quantity is reduced 200 inches, at 30 miles to 100 inches. The higher parts of the current clear the mountains, and are caught by the lofty ranges of the Bhotan Himalaya, which, while arid and treeless below 6000 ft., above that level are well watered, and nourish a luxuriant vegetation. The W. Ghauts also receive a prodigious quantity of rain. The stratum of saturation ready to deposit its moisture on the slightest reduction of temperature is here about 2000 ft. above sea level; but when driven by the wind against the wall-like barrier of the range fronting W., the rain-clouds rise to heights very much greater, and suddenly cooled deposit a maximum quantity at 4500 ft. of elevation. The quantities at a few stations are as follows:—Uttray Mullay 9° N., at 4500 ft. 263·21 in., at 6200 ft. 194 in.; Mahableshwar, 18° N., at 4500 ft. 254·84 in.; W. Ghauts generally 82 in. to 101 in.; sea coast 76 in. to 82 in.; at Poonah, 50 miles inland and 1823 ft. above the sea, 24 in.; such is the effect of the mountains in causing a deposit of rain. Dissolved in the hot air over the Deccan, the rain-clouds deposit little on the E. coast, which has its rain from the N.E. monsoon chiefly. While this wind prevails (Oct.—Dec.), Madras has 30 inches of rain, in the other 9 months only 19; Cuttak gets 50 inches of rain from the same wind, while Aracan, on the opposite side of the bay, has from the S.W. monsoon 200 inches. A remarkable instance of the effect of a range not very lofty in arresting rain-clouds is seen in Ceylon. The central N. and S. ridge nowhere passes 8280 ft., yet it so completely stops the passage of the rain-clouds of both monsoons, that while the country is deluged and the rivers brimful on one side, on the other the crops are suffering from drought, and a scanty supply is doled out to the plantations from tanks filled under the monsoon six months before.

63. Rain of Temperate Regions.—The quantity of rain decreases as we recede from the equator, but the number of rainy days increases. The average number in the tropics is 78 days, thence to lat. 43°, 80 to 85; from lat. 43° to 46°, 103 days; lat. 46° to 50°, 134 days; lat. 50° to 60°, 161 days. St. Petersburg, in lat. 60°, has only 17 inches of rain, but 169 rainy days; Paris has 22 inches, and 105 rainy days. (Art. 9, Europe.) The summer solstice is a season of unusual precipitation over the temperate zone owing to the high limit of the trade wind at that period. In **N. America** the rainfall on the W. coast, owing to the direction of the wind and conformation of the coast, increases from 22 in. at San Francisco to 90 inches at Sitka. The circumstances of the country inland have been noticed already (Art. 36-37). The rainfall is greatest in the Gulf States, and diminishes northward. The quantity is uniform over very large areas, and the plains have more than the Alleghany mountains; 64 to 50 inches in the S.; 50 to 36 in the N. parts. In the N.E. States the distribution is like that of Europe, fall 45 to 27 inches. In **S. America** to beyond the tropic, the rain is brought by the S.E. trade, whose influence extends as far as the Andes. In the narrow southern promontory the fall of rain or snow is almost incessant.

The W. coasts of Europe present strong contrasts to the central and eastern. The W. coast of Portugal has 73 to 118 in.; W. of France 50 to 70 in.; inland the fall is 30 in.; at Paris 22 in.; the plains of Germany and Russia have 20 in.; parts of Sweden and Russia only 15 in.; while Bergen has 89 in., Upsala has only 22 in.; and Uleaborg 13 in.

In the **British Isles** the rainfall is most copious near the great ocean, which is the main source of warmth also, especially near high mountains and in deep valleys opening S.W. The quantity diminishes towards the centre and E. coast. The greatest known rainfall of these islands, and the greatest known anywhere, except the few above-mentioned, occurs in the lake district of Cumberland. The mountains here rise abruptly from the Irish Sea, towards which three principal valleys open out. These receive the vapour as it is borne inland, and rapidly condense it against their continually approaching sides, so that in Eskdale one-fourth more falls at the head of the valley than in the middle; at the lower part of Ennerdale twice as much as in the open country three miles distant S.W. As the heads of the valleys are reached a few hundred yards make a remarkable difference. The greatest deposit of rain takes place 100 yards S. of the top of Stye Head Pass at the height of 1077 ft. above the sea. The amount here varies from 165 to 224½ inches, and 1½ miles E. diminishes by 40 to 60 inches. The plane of saturation is at 1463 ft. elevation; on the top of Scawfell (3166 ft.) the quantity is only 64 inches. The axis of most rain runs from this group by Fairfield to Howgill Fells. The eastern mountains as a rule have about half as much as the western. Thus Skiddaw at 1677 ft. has 55 inches; Keswick 59 inches. In regard to other parts of the United Kingdom it may be stated generally that the fall is from 40 to 110 in. where hills are near, and 35 to 45 in level tracts; on the eastern side 20 to 30 in. Isle May has a rainfall of only 15·97 in., Durham 17·76 in.; these are the lowest known in the United Kingdom. The following rainfalls are the averages of many years:—London 23·5 to 25·4; Manchester 36; Liverpool 35; Glasgow and Baillieston, 43·23; Paisley 47·62; Bothwell 27·58; Auchinraith, near Hamilton, 30·08; Cambuslang 29·25; Mugdock reservoir 48·27; Edinburgh 26·67; Dublin 28·87; Belfast 34·96; Cork 40·20; Carlisle 42; Londonderry 31·12; Greenock 62·25. The greatest recorded quantities received in any rainfall that are trustworthy vary from 1 to 1¼ in. per hour. During a rainfall, in ascending vertically over any surface free from eddies the quantity diminishes by a very small quantity as we ascend, amounting to about ·08 to ·12 of an inch for 25 ft., but not decreasing regularly.

The cause is obscure; accretion of drops is insufficient to account for the difference. The absolute quantity falling on high grounds in a given time is of course greater than at low levels.

64. Clouds.—The study of clouds in their ever-changing forms and beauteous play of colour is one of great interest; but it can only receive here the briefest notice. There are three primary and four secondary forms, according to the classification first proposed by Mr. Luke Howard of London in 1803, and still retained by meteorologists. 1. The *Cirrus* or



CIRRUS, OR CURL-CLOUD.

Curl Cloud. It consists of slender filaments stretched out at a great height on the background of the sky, in wavy or twisted, and in parallel or divergent forms. It is the highest and therefore the lightest of clouds, and must often be composed of minute ice-crystals, or of thin snow-flakes. It is chiefly an indication of the movements of the equatorial current (Art. 57); and when it begins to appear upon the sky, especially after a day of N. wind, is an unerring sign of approaching wet and stormy weather. Yet it often appears night after night in calm, hot weather, and is dissolved again in the heat of the day.—2. The *Cumulus* is the massy and fleecy cloud



CUMULUS.

of the lower and middle sky, formed from the vapour sent up from the moistened Earth by the play of the Sun's heat as the day advances, "at first no bigger than a man's hand," but gradually enlarging by accretion of fresh vapour, till the grand features of a mountain range are attained. Cumuli sinking to low levels, and remaining into the night, often give out rain. Fleecy outriders from their sides announce speedy rain.—3. The *Stratus* is a continuous wide-spread layer of cloud or vapour, whose lower surface rests on the earth, and which increases from below upwards. It is the cloud of the night, as the cumulus is that of the day, and originates in the condensation of the mists formed about



STRATUS.

night-fall in low-lying cold river-flats and the bottoms of valleys. In fine weather the stratus is broken up and dissolved by the morning warmth; but it often becomes permanent and passes into a rain-cloud. — The compound forms are: 1. *Cirro-cumulus*, consisting of small streaky, rounded masses of cloud formed from the cirrus, with clear spaces between (Art. 59); when the masses are small it forms a "mackerel sky." 2. The *Cirro-stratus*, composed of streaky, compactly-fibrous clouds, thin at the edges, which rapidly spread from the breaking up of other forms; they are usually the precursors of rain and storm. It is upon these generally that halos and mock suns and moons are formed. 3. The *Cumulo-stratus* combines two other forms; the stratus being interstratified with the cumulus, or broadly massed against it as a horizontal base. Another and distinct form of it is seen when numerous fleecy outriders appear upon the sides of the cumulus just before rain. 4. The last form is the *Nimbus* or *Rain-cloud*, called also the *Cumulo-cirro-stratus*. It is formed by the cumulus drifting with the wind under sheets of the cirro-stratus; a uniform mass is thus soon formed, and the rain-cloud produced, with its mass of saturated vapour. Cirri often shoot up from the top of this rain-cloud as it drifts along, greater in number according to the amount of rainfall.

Rain often falls from the sky when there is no visible cloud. To rain of this kind the French give the name of *Serein*. It has been suggested by Sir. J. Herschel that water may exist in a filmy invisible condition in the lower air, and be taken up by drops as they fall through it, thus increasing the quantity received at low levels (Art. 63).

65. Rainless Tracts.—The rainless districts of the globe are the unshaded portions of the Map in the heart of Africa and Asia, and on the W. coast of America. That of Mexico is accounted for by the deflection of the trade wind up the valley of the Mississippi (Art. 37), and there being no wind from the Pacific in that latitude to waft the rain-clouds. The desert of Peru is under like conditions; there is no wind from the Pacific, and the S.E. trade of the Atlantic gives out its residue of moisture to the high Andes behind (Art 63). The circumstances of the rainless tracts of Asia and Africa are different. In the summer of the northern hemisphere these are traversed by the N.E. trades, which have their origin on land further N. than at sea, because the heat along the medial line (Art. 54) is greater on land. On reaching Persia, Arabia, and Africa, these

winds are very dry, having travelled over land, and any vapour they may hold is being continually more rarefied by the warmer air amid which they come. The moisture licked up from the narrow Levant is too small to moisten the winds, and they blow across this sea and the E. Atlas in a dry state, bringing no moisture to central Africa. In winter when the medial line retires S. the return current might be expected to bring rain; but the anti-trade does not so soon sink to the surface, and is too little cooled, being over the warm intertropical land, to give out any residue of moisture not lost in the cloud-ring. The S.E. trade monsoon of the E. coast of Africa, which causes the swellings of the Nile (Art. 58), cannot reach the heart of the continent, being arrested by the Abyssinian Alps; while the S.E. trade of the gulf of Guinea merely crosses the great western promontory, rendering it the most prolific region of vegetation on the surface of the globe. Again, the left wing of the monsoon (Art. 58) lightly grazes the N.E. horn of Africa and the S.E. coast of Arabia, making the Somauli country and "Araby the blest" one of the richest regions on the earth; thence the monsoon sweeps round the head of the Arabian sea, not reaching the high plateaux of Persia and Khorassan, which, as being just outside the tropic, are not under the influence of the variable winds and the rains which accompany them, and are thus in the arid or rainless tract.—The eastern division of this tract, the great desert of Gobi and Shamo, lies under the cold dry winds of Siberia, blowing towards the heated region of S. Asia, and becoming continually warmer and drier as they advance, while it is shut off from all contact with the South West monsoon by the lofty barrier of plateaux and mountains. It can derive no moisture from the anti-trade or return current, which has already subsided so far in the atmosphere as to be arrested in its northward progress by this same lofty barrier.

66. Whirlwinds.—Whirlwinds are caused by the contact of two opposite currents of air; eddies thus arise which gradually force a body of air into rapid rotation. Such force is often generated in this way that houses are unroofed, branches torn off trees, and clouds of dust borne aloft. Occurring at sea they carry up columns of water, and then scatter them over a wide space. Similar vorticose movements are often produced on the under surface of rain-clouds, doubtless by a difference of temperature; the vapour is formed into long hollow tapering appendages like tails, which often descend to the surface and discharge in heavy rain; and have sometimes been seen to raise the water from the surface of the sea, as in the case of a whirlwind (see Map).



WATERSPOUT.

67. Temperature in Altitude.—It has been already pointed out how irregular is the diminution of temperature with the latitude; not less irregular is the change as regards altitude. The decline vertically was formerly taken, from observations made on mountain sides, at 1° F. for every 300 ft. The balloon ascents of Mr. Glaisher, begun in 1862, have shewn this estimate to be erroneous. The temperature was often found invariable through very considerable heights, in one case as much as 1800 ft; warm and cold currents were found to alternate at various altitudes, both alike retaining the same temperatures through very considerable heights. Thus after various changes at lower levels, a temperature of 37° F. was experienced at 3000, 6500, 8500, and 11,000 ft. As high as 4½ miles a warm current was found overlying a colder one. In a January ascent, snow at 6000 ft. was falling into a warm current 3000 ft. deep, and melting. In an ascent in September, the zero of Fahrenheit was reached at 24,000 ft.; and at 7 miles, or 37,000 ft., the highest point reached, and where life was possible for a very brief space only, the temperature was −11°·9 F., the barometer stood at 7 in., the sky was not black, as we have been always told of great heights, but of an intense Prussian blue, and the air so excessively dry that the colour must be ascribed to the polarization of sunlight by the particles of the air itself, at the polarizing angle of 45°. So irregular were the results as regarded temperature, that no law of decrease could be fixed; but as a tolerable average for the early afternoon hours within the first 1000 ft., we may take a fall of 1° F. for 223 ft. with a cloudy sky, and 162 ft. with a clear sky; at 10,000 ft. the spaces will be 455 and 417 ft.; and above 20,000 ft., 1000 ft. for both states of sky.* No observations were made during night, but it is considered most probable that the temperature then increases upwards. It is much to be desired that a like series of ascents should be made by night, and also remote from oceanic influence, as in central Germany or the E. of France.

68. Dew, Hoar Frost, Hail, Snow.—In a clear night when the surface of the ground freely radiates heat into space, moist air in contact with a body on the surface deposits minute globules of water

*See Mr. Glaisher's *Travels in the Air*, published Jan., 1871, a work of remarkable interest; also *Brit. Assoc. Rep.*, 1869.

upon it: this is Dew; and if the temperature of the body be below the freezing point, the particles are frozen, and Hoar Frost is formed. Radiation is stopped, and the formation of dew or hoar frost prevented by stretching a cover, even of a thin gauzy substance, over any surface, at a moderate height. Frozen drops of water constitute Hail; if suddenly formed by the irruption of a cold current into a mass of saturated air, hailstones are simply masses of ice; when formed more slowly they have a radiated or concentric structure, or a combination of both. It is usually considered that vapour must pass into the liquid state before assuming the solid form of snow; but as the late admirable researches of Dr. Andrews (*Phil. Trans.*, 1869, P. II.) have shewn that the gaseous and liquid states are continuous, it is conceivable that this may not be necessary. In thus solidifying, the snow assumes crystalline forms of wondrous beauty, numbering nearly 1000 varieties, all built up of one primitive form, a minute rhomb, whose angles are 60° and 120°.

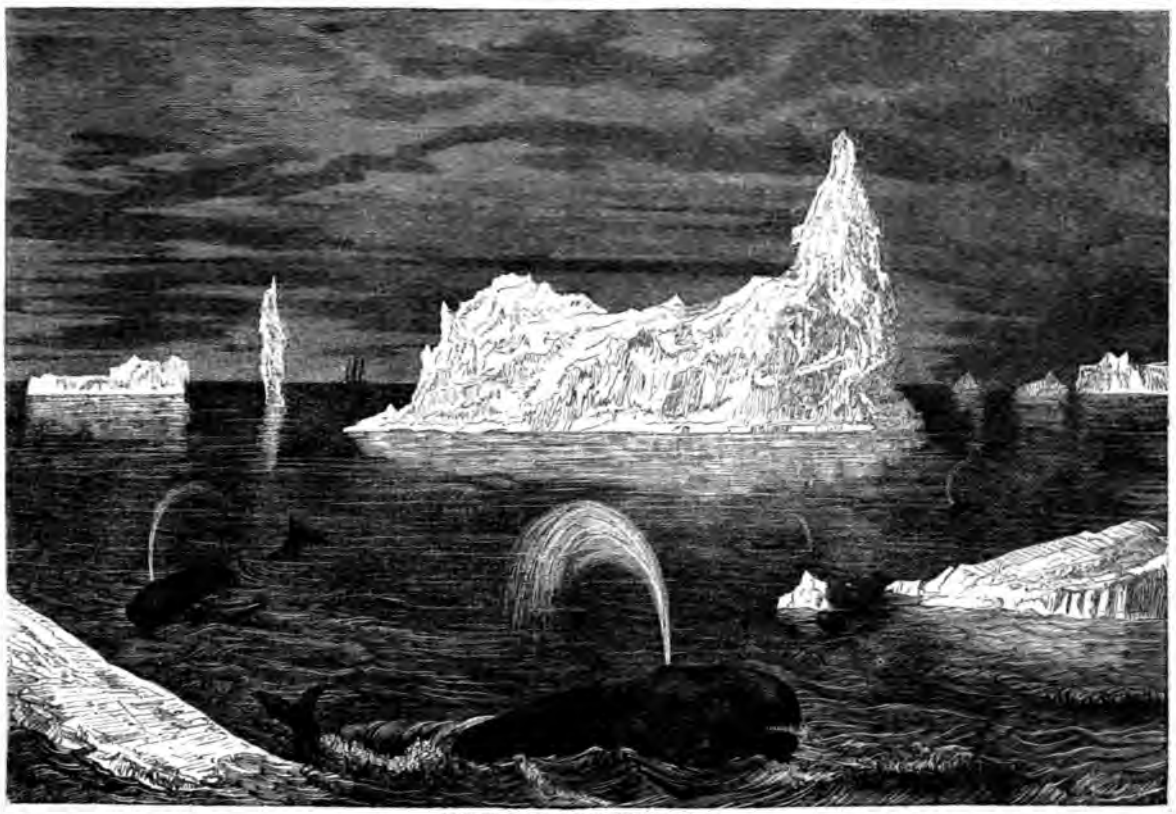


SNOW CRYSTALS.

The snow-flake varies in size from ·07 of an inch to 1 inch in diameter, being largest when the temperature is near 32° F., and smallest at very low temperatures. What is called "red snow" is really a minute lichen (*Protococcus nivalis*), which finds nourishment on the highest snow-fields and in the Arctic regions, and propagates itself in a single night over large surfaces. A green variety of it is frequently met with.

69. The Snow Line. — The results above stated shew that while latitude and altitude are mainly influential in determining the line above which more snow falls in winter than is melted in summer, local conditions will cause great variation; and the determination of a law is impossible. All the elements involved are of a complex character; the ratio of transmission of heat varies with the air's density; the ratio of absorbability varies for the different rays, and these ratios are as yet undetermined. It is known, however, that a given volume of dense air is more easily warmed than the same volume of rare air; and that heat disappears, or becomes latent, by the process of rarefaction; as is well illustrated by the common air-pump experiment, in which a thermometer falls and a cloud appears in an exhausted receiver; the readmission of the air dissolves the cloud, and causes the thermometer to rise. The permanency of snow under the Sun's vertical rays in tropical regions depends on this principle, and is the more remarkable when we consider the prodigious power of solar radiation in dry air at great altitudes. This is familiar to every one who has traversed the Alpine snows. Prof. Piazzi Smyth found that when the temperature of the air in the shade to the north of his tent was 60° F., the black-bulb thermometer (absorbent of all the rays) exposed to the direct rays of the Sun on the S. slope of the peak of Teneriffe, rose to 210°·4 F., the radiation thus exceeding the temperature by 150°! A piece of black cloth, which passed the heat through, sank rapidly into the snow. The existence of perpetual snow, then, must be independent of direct radiation, and be due to the low temperature of the dry rare air, the non-conducting power of ice, and the reflexion of heat from the glassy surface of the frozen mass. The actinic or chemical rays are, however, more powerful at great altitudes, as De Saussure long ago shewed, and as Prof. Smyth found on Teneriffe in the greater intensity of photographic pictures, and the ease with which they were taken. This subject has been lately reconsidered in a series of experimental researches by Professors Roscoe and Thorpe, as yet only partially published, *Phil. Trans., 1870.* Prof. Thorpe has kindly made known to me the following results:—That under 10° altitude of the Sun, direct sunlight has no chemical effect; that up to an altitude of 35°, diffuse daylight has more effect than direct sunlight; above this altitude, the effect of direct sunlight is greatest; that the action is greater in warm weather than in cold; and that the humidity of the air has little or no influence.—De Saussure calculated that at the top of the atmosphere, the temperature of shade would be −50° F., while the effect of direct sunlight would be increased hundreds of degrees.

70. The Snow Levels. — The level of perpetual snow is higher in a dry climate than in a moist, because both snow and ice evaporate, without melting, into dry air. In the S. Himalaya, lat. 26° to 30° N., which are reached by the S.W. monsoon, the level is 15,500 ft., while in the northern range, 30° to 36° N., it is 19,500 ft., and in some places more than 20,000 ft.; the rise in level is gradual northwards in exact correspondence with the increasing dryness of the climate. Similarly in S. America, within the limits of the S.E. trade, the snow line is lower on the E. side of the Andes than on the W., the limits being 15,900 and 18,500 ft. When the S. limit of the trade is passed, the rule is reversed, the Pacific being then the source of moisture. In the very moist climate of the S., the snow level is low for the latitude (see under Map XV.) For a like reason the level is higher in Eastern than in Western Europe in the same latitude. The levels on the principal chains are as follows:—Alps, 8500 to 8885 ft.; Pyrenees, 8950 ft.; Caucasus (same lat.),



ICEBERGS OFF NEWFOUNDLAND.

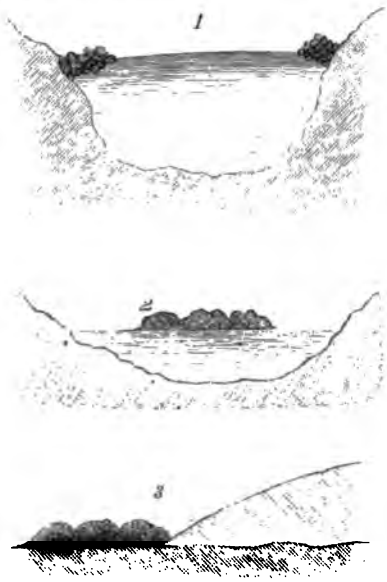
11,063 ft.; Sierra Nevada, 9500 ft.; Himalaya (same lat.), 19,500 to 20,000 ft.; Norway, lat. 60°, 4450 ft. near the coast, 5500 ft. in the interior; 66° N., 3250 ft. and 3700 ft.; 70° N., 2900 ft. and 3350 ft.; 71° N., 2500 ft. In Spitzbergen, 80° N., sea level on E. coast, same as in S. Georgia in lat. 54° S.; on the W. coast, same as at the N. Cape. In the Andes, 54° S., 3500 ft.; and some glaciers reach the sea; 43° S. in Chili, 6000 ft., which would be the snow level in Scotland in 57° N.; 40° S., 8300 ft.; 33° S., 12,750 ft.; 27° S., 13,800 ft.; 17° to 23° S., Cochabamba and other cordilleras, 17,000 ft. to 20,000 ft., where the climate is very dry; near the equator, 15,500 to 15,820 and 16,000 ft. Rocky Mts., 40° to 43° N., 12,500 ft., or 6000 ft. higher than in the same latitude in Chili, and 3000 ft. higher than in the same latitude in Europe (see diagram on Map). The *mean* temperature of the snow line in the Alps is about 25° F.; in Norway, 23° F., but in many places it is 20° F., and in some as high as 35° F. (Buchan, *Met.*, Art. 431.) Oonalaska and Kamtschatka on opposite sides of the Pacific, in nearly the same latitude (56°—59°), have the level of perpetual snow at 3510 and 5250 ft. respectively. Altai Mts., 50° N., 7040 ft.; Aldan, 61° N., 4476 ft.; Hindoo-coosh, 18,700 ft.; Ararat, 14,170 ft.; Argish, 10,700 ft.; Abyssinian Alps, 14,065 ft.; near the Equator, in Africa, probably 18,000 ft.

71. Glaciers.—The changes of the seasons, alternations of day and night temperatures, and superincumbent pressure convert snow above the line of "perpetual congelation" into a peculiar kind of ice, porous and viscous, more consolidated than snow, but less hard and rigid than the ice of our lakes and rivers; of this ice glaciers consist. They are huge ice-rivers occupying the valleys on mountain declivities, and fed by the masses of altered snow on the higher mountains and snow-fields. Under the influence of forces, regarding whose nature and mode of operating there is still much discussion, they glide down the valley with a velocity depending on the slope,



GLACIER D'ALETSCH.

nearly as great in winter as in summer, and always greater along a certain medial line than at either side. They extend downwards through many miles, and often thousands of feet vertically below the snow line, into the forest region, and even to the corn-fields and vineyards. The extremity of the lowest on the Alps, the Grindelwald glacier, is at the height of 3409 ft. only above the sea, the snow line there being 8500 ft. The form of the floor, and more rapid forward motion of the central parts, give to many glaciers a very broken and rugged surface, and promote the formation of clefts or crevasses, by which the ice is rent, with a loud noise, through long distances and to great depths. When these are narrow at the surface, and get covered with fallen snow or drift, they are a source of great danger to one passing across the glacier. The glacier bears on its surface many huge blocks, small stones, and earth, which have fallen from the steep sides of the valleys, all of which are mostly arranged in long streams or lines upon the surface,



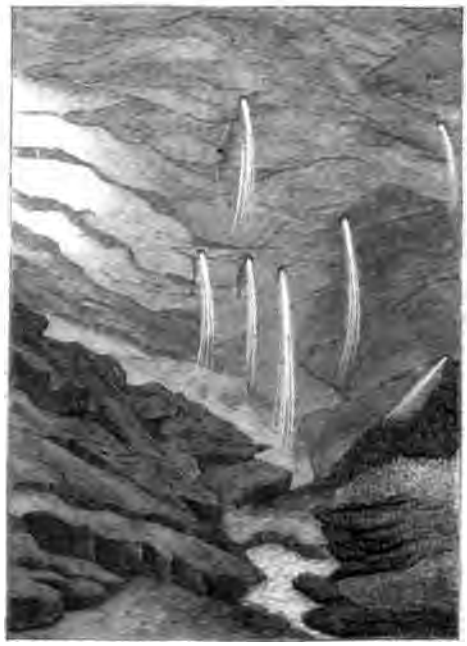
MORAINES.

called Moraines. These are of three kinds:—(1) Lateral, on the borders near the rocky sides of the valley; (2) Medial, forming rows down the middle, caused by the junction of two glaciers, when one of the lateral ones of each passes into the mid-stream of the united mass; (3) Terminal, formed by the rubbish thrown down at the extremity when the glacier melts.—Blocks often sink to the bottom of the glacier, and are carried along in the stream, striating and polishing the rocks below; others of a broad flat form rest on the ice, which is thawed away round them by the reflected heat, and form "glacier tables," standing for a long time at a considerable height. From ice-caves at the extremities of glaciers many rivers issue in Alpine countries. The Ganges and Indus, Yang-tse and Whang-ho, Rhone, Rhine, and many others, have such an origin. The whole mud of these glacier streams is



GLACIER TABLE.

deposited in the first lake through which they pass. Glaciers in the Polar regions often reach the sea-level, when vast masses float away and form the ice-bergs, which descend from their birth-place into climes far southward, and form a serious danger in

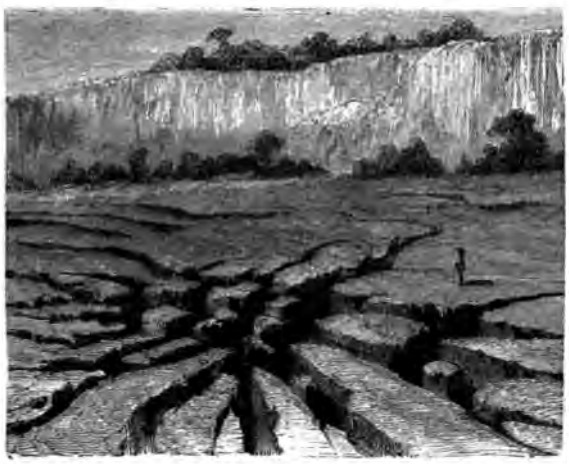


GLACIER SOURCES OF THE RHINE.

navigating certain tracts of the ocean. Such is the buoyancy of ice, that from 6 to 8 times more is above the water than below it. The bergs are often from 100 to 400 feet in height with vertical walls, and from 2 to 5 and rarely 10 to 13 miles in length. Thousands of tons of stones and earth are often carried by them, to be thrown down when they strand on some distant shore.

MAP XIV.—VOLCANOES AND EARTHQUAKES.

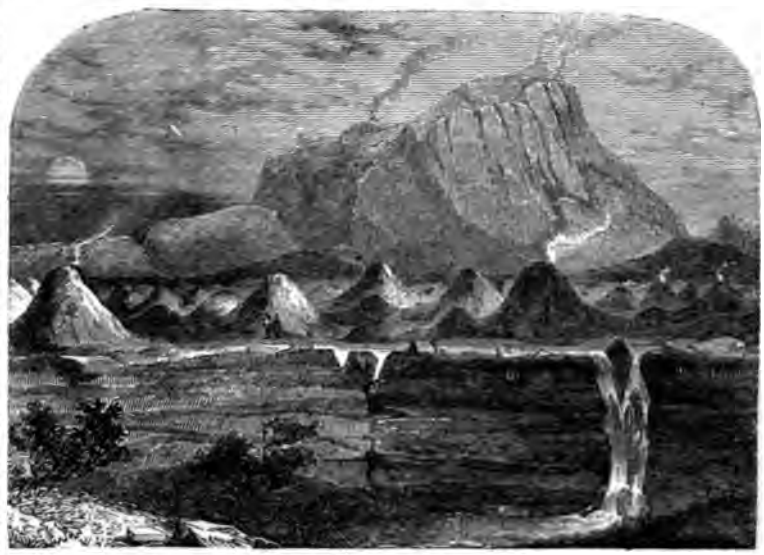
72. Theory of Volcanic Action.—The history of volcanoes and earthquakes forms rather a chapter in Geology than in Physical Geography. It will be sufficient therefore to describe the distribution of volcanoes in order to complete our outline of terrestrial phenomena, and the changes in Physical Geography produced by earthquake movements.



EARTHQUAKE FISSURES IN CALABRIA.

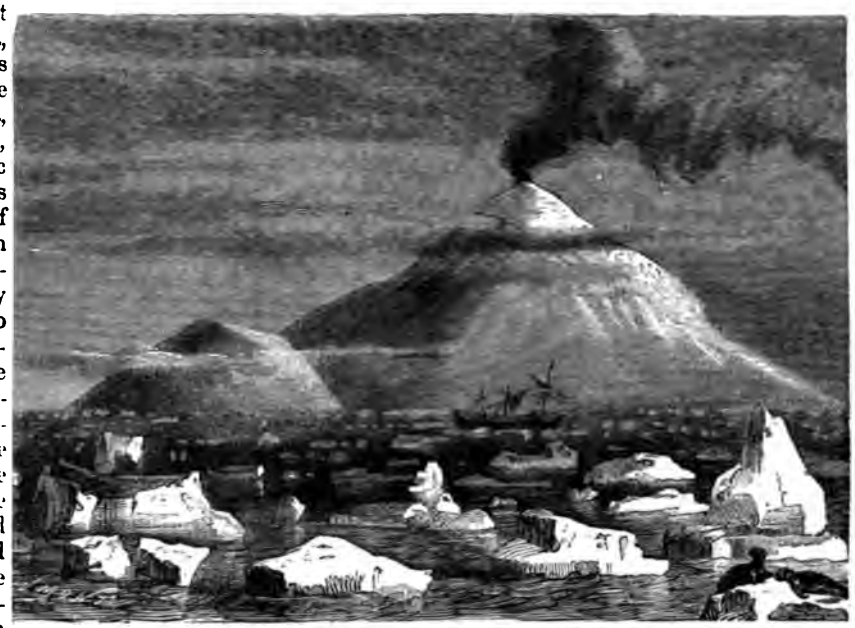
The combined researches of mathematicians, astronomers, and geologists, have within a few years shewn us that the Earth is not a thin shell of solid material enclosing a hollow space filled with liquid; but that the Earth must be solid through a long distance from the centre, certainly not less than one-fourth of the radius, including therefore more than half the volume. But the fact that in all countries there is a progressive increase of heat downwards, amounting to 1° F. for every 50 ft. of descent, independent certainly of all solar influence in past time, and also the phenomena of volcanoes, prove that the Earth has a proper internal heat. All the reasonings and the phenomena are reconciled by supposing that this arises from matter such as forms the solid part of the globe, the earths and alkalies, metals, and other simple substances, existing in the state of igneous fusion in detached liquid basins or "lakes of fire," as under separate volcanoes, which may have channels or tunnels of communication with one another through long distances. This igneous matter may be but what remains unsolidified from a state of original fluidity of the whole Earth; or we may suppose it produced by chemical changes, such as the action of water on the metallic bases of the earths and alkalies, and the play of other affinities combined with electric agency, if such a succession of changes can be supposed to go on without having something of the contradictory character of endless cycles or of a perpetual motion. The upward propulsion of the melted matter and its escape through open vents, may be but a boiling over, or it may be due to the action of imprisoned vapours; while earthquakes may be caused by masses falling from the roofs of cavities, or by steam or vapours rushing violently through long passages in their efforts to escape. The undulation perceived in earthquake movements is similar to that produced by dropping a stone into water; and proceeds in the same way from a focus or centre where the impact from below, or other disturbing cause, is the greatest. When this focus is under the ocean floor at no very great distance from land, the wave sent in upon the land carries the most fearful destruction in its course. The disposition of all the volcanoes of the globe close to the sea, except two, and these have lakes in the neighbourhood, lends probability to the view that access of water and the generation of steam play important parts in these volcanic phenomena.

73. Distribution of Volcanoes.—Almost all the volcanoes of the globe are situated on a comparatively narrow band encircling the Pacific Ocean. We begin at its southern extremity. Tierra del Fuego and Patagonia through 10° of latitude are without volcanoes, recent or extinct, though igneous rocks of the old types abound. The island received the name from a peculiar light seen upon it by the first navigators, the cause of which has not been explained. Yanteles, in lat. 43½° S., is the first volcano. From this point northwards, with occasional interruptions, the Andes are a volcanic chain. Granite and the old rocks generally do not rise here higher than 11,500 ft.; the mountains above this level are built wholly up of various volcanic products. The prolongations through



THE JORULLO, MEXICO.

Central America, the West Indies, and North America, have the same character, as far as Behring Strait, where the promontory of Alaska, 350 miles long and 25 broad, is studded with volcanic cones, some of enormous height. The other parts of the continent are free from volcanoes; and the earthquakes which so frequently disturb the regions close to the mountain chain, are propagated but a short distance eastwards of the axis. Earthquakes have rarely been experienced in Canada; twice of great severity in the Mississippi valley. The volcanic band is continued in the Aleutian Isles and Kamtschatka, in the Kurile and Japan Isles, the Philippines and Moluccas, through Java and Sumatra, up the Bay of Bengal on the Burmah coast, and ends in Barren island opposite Chittagong. In Japan earthquakes are more frequent than in any region of the globe. The Himalaya and Suliman mountains, and those within India, are without volcanoes; but earthquakes are occasionally felt in both chains, and along the lower basin of the Indus. In China, also, they occur rarely; but this country has many thermal springs. In the Thian-shan, or Celestial mountains, about the meridian of 90° E., there are two lofty volcanic cones; the plains northwards, and the Altai south-west of Lake Baikal, shew also a few volcanic cones and solfataras; while this whole region is subject to occasional earthquakes. Proceeding westwards, we have the great cone of Demavend, south of the Caspian, and an important group ranging south-west from Ararat; while both extremities of the Caucasus have mud volcanoes and hot springs, and along the south base of the chain earthquakes are frequent. The peninsula of Asia Minor has no active vent; but a large tract in the west, the Kata-kekaumene, is covered with products of extinct fires. The eastern shores of the Red Sea have a volcanic region, said to be 10,000 square miles in area. The British settlement of Aden is on its lower margin, and the town is built on an old crater with a seaward breach. A small lineal group, of which Santorin is the centre, has been active in historic times; and earthquakes have produced important changes in Syria and on the shores of Greece. South Italy and Sicily are the most celebrated theatres of recent action; extinct volcanoes occur near Rome, in central France, on the middle course of the Rhine, and in the eastern angle of Spain. One of the most tremendous earthquakes on record had its focus under the Atlantic near Lisbon, and was felt from



MOUNT EREBUS, ANTARCTIC CONTINENT.



MOUNT ETNA.

Syria to Lake Superior, from the borders of the Sahara to the south of Norway. Hence the focus of disturbance must have been very deep-seated. The wave of the Arica earthquake of 1868 traversed the entire breadth of the Pacific. The pelagic group of the Azores, 800 miles west of Gibraltar, of recent volcanic origin, almost brings into connection the volcanic region of the Old World with that of the West Indies, and thus completes our circuit of the globe. Australia and Africa are without volcanoes, and earthquakes are not known to occur except in the region of the Atlas in the north-west of Africa, and there they are observed to be simultaneous with those which affect the Mediterranean shores on the north. Many of the pelagic isles of the Atlantic, Pacific, and Indian Oceans are volcanic. The N. island of New Zealand exhibits recent volcanic action; and both islands have frequent earthquakes. Victoria continent, near the South Pole, was found by Sir J. Clarke Ross to be the scene of extraordinary activity on a very grand scale. The Arctic regions have, in Iceland and Jan Mayen on the east coast of Greenland, vents in frequent eruption; and in the northern archipelago there are many traces of foci long quiescent.

Earthquakes occur far beyond the limits of those districts where there are active volcanoes, and cannot be traced to a contemporaneous disturbance in any volcanic region. Thus, portions of Scotland and Ireland, from the Moray Firth to Galway Bay (Art. 47), are often disturbed, as well as parts of Perthshire and the N. and W. of England.

Important changes in physical geography are now going on under the influence of volcanic forces. The whole N. of Europe, and most probably of Asia also, is rising at the rate of 3 to 5 ft. per century; and this has gone on so long that the country has risen 400 ft. The coast of Greenland and west coast of America have undergone great changes both of elevation and subsidence; and vast areas in the Pacific and Indian Oceans have been mapped out which are the theatres of both movements. The theory is, that the areas of subsidence are marked by the lagoon coral islands or atolls, such as the Laccadives, Maldives, and Chagos, which have a ring of coral encircling a quiet lagoon, connected to the ocean by a narrow strait on the side turned away from the prevailing wind (see Map); and also by the Barrier reefs, like that of New Caledonia, or that of Australia, which stretches along the E. coast for 1000 miles S. of Torres Strait, at 20 to 50 miles from the coast, with the water inside only 12 fathoms deep. Areas of elevation are marked by the fringing reef, which encircles the whole coral island at a small distance, and has shallow water inside the reef, while the unfathomable ocean breaks in a constant surf against the outer edge. The pelagic isles of all the oceans are either of coral formation or volcanic origin, or both united, except New Caledonia, the Seychelles, and Saxemburg in the S.W. Atlantic.

MAP XV.—OCEAN CURRENTS AND RIVER BASINS.

74. Origin of Currents.—The ocean has a great system of circulation like that of the atmosphere, due to a difference of temperature in the oceanic waters and to the action of the trade winds. A like uniformity in the flow over wide areas, and the same regularity of direction are not to be looked for on account of the interference of the land masses, their irregular outlines, the uneven character of the floor of the ocean, and the heating of the water taking place downwards, while that of the air is upwards. At the equator a depth of 1200 fathoms must be reached before we find a temperature so low as that which prevails at the surface in latitudes of 65° to 70°; between the surface waters there and those at the equator there is a difference in temperature of 40° to 45° F., which seems sufficient to establish the circulation we actually find in the ocean —warm surface currents travelling from the equator, and cold under-currents towards it. Salt water freezes at 27°·5 F., and has no point of maximum density under this, as fresh water has. The surface cold of the polar regions increases the density and lowers the level of the waters, and a tendency to sink is given to each stratum, exposed in succession to the cooling influence, as it flows to the lower level from the surface of the area of warmer water all around. The equatorial heat, on the other hand, raises the level and diminishes the density of the superficial strata, and gives the tendency to overflow towards the poles, the place of the water so withdrawn being supplied by the water which has sunk and been drawn in beneath from the polar basin. The constant descent of ice-cold water will generate a slow downward and backward current, which will gradually acquire an upward movement as it nears the equator, from each new arrival of cold water taking its place beneath that which has gone before it; so that this polar water may thus reach the equatorial surface, and return N. in the same cycle.*

75. Currents of the Atlantic.—The great circulating system of the Atlantic, certainly the most remarkable, as it is the best known, of the globe, goes under the names of the Equatorial, Brazil, and Guinea currents, and the Gulf Stream.—The Equatorial current is first distinctly recognized about lat. 20° S. on the African coast, and near the equator becomes gradually deflected W., partly by the form of the land, and partly by the pressure of the N.E. and S.E. trade winds, and passes across the ocean near the equator with a breadth of nearly 10°, and a velocity varying from 15 or 16 miles per day to 36 or 50 miles, the velocity being greatest in the northern summer; it is colder than the ocean adjoining, being 72° to 82° F. according to the season, while the ocean is never under 80°, and in summer

* See an important paper by Dr. Carpenter in *Proc. R. Geog. Soc.*, March, 1871. An illustrative experiment is there described:—A narrow water-trough with glass sides is heated from the surface at one end by a metal bar acted on by a spirit-lamp, and is cooled at the other by a mass of ice wedged into the right angle at the top. The circulation of the water is then seen to proceed exactly as above described; cold applied at the surface becomes a force like heat applied below.

84° to 86° F. Impinging on the projection of S. America at Cape St. Roque it divides into two branches, one runs down the coast of Brazil, the main body along the N.E. shores of S. America, through the Caribbean Sea, and into the Gulf of Mexico. It is so rapid along the shores of the Spanish main, from 54 to 63 miles per day, that vessels bound west gladly enter it.—Pent up and heated in the Mexican Gulf, which is constantly in the condition of a caldron of hot water lipping to overflow, it seems to gain a small head of water, and to acquire a depth which the trade wind could not give, for this acts to produce but a surface-drift. Thence it issues through the narrow Florida Strait with a velocity of 4 or 5 miles per hour, and is henceforth called the Gulf Stream, its course being clearly marked by the deep indigo of its waters, and its not sparkling at night. The width is 32 miles, and depth 200 fathoms; off Cape Hatteras it is 500 miles from the coast, and 75 miles wide, 114 fathoms deep, and runs at 3½ miles per hour. This shallowing northwards is due to its buoyancy in relation to the colder and heavier water among which it has come. —Even as far N. as off Newfoundland the velocity has been found in summer to be 4 miles per hour. The temperature in the S. part is from 5° to 11° F. warmer than the ocean; but off the Great Banks in winter it is often 20° to 30° F. above it. It is here often covered with fogs from the coldness of the surrounding air. Owing most probably rather to its excess of rotatory velocity eastwards (Art. 57) than to any obstacle met with in shoals or banks, the stream curves gradually eastward, and divides into several branches; one of these sweeps round southward, and is diffused over a large tract of ocean 8° to 10° warmer than the water outside, and covered with masses of sea-weed, the *sargassum bacciferum* (*fucus natans*, Lin.), so thickly interlacing that snips in many parts cannot force a passage. This is the Sargasso Sea; the arrows inside suggest eddying currents, to which, doubtless, is due the accumulation of sea-weed within nearly the same limits since the date of its first discovery by Columbus. About 42° N. 38° W. a branch turns S.E. and then S., traverses the western shore of Africa as the Guinea current, and enters again the same circulation on the equator. The velocity is from 2 to 3 miles per hour; and we have thus the remarkable feature of two great ocean streams running in opposite directions almost side by side for 1500 miles through the gulf of Guinea, with velocities like those of the Mississippi and Danube.—Off the Newfoundland banks the depth of the stream decreases to 50 fathoms; and it is held by many that thence northwards the warm water should be regarded as a surface-drift rather than a "stream." This body of warm water passes on continuously into the Arctic Sea, as manifested in the deep concavity of the isothermal lines as far as 80° N. (Art. 52). Mahogany trees, cocoa, several kinds of pear, cashew nuts, and seeds of *guilandina bonduc*, are thus cast upon the west coast of Ireland, the Hebrides, and Norway. The last-named plant, a native of central America, has been raised in hothouses in Galway from seeds thus transported. The Spanish species of heath got in the W. of Ireland have no doubt a like origin, and the Canadian *Eriocaulon septangulare* of the outer Hebrides.—Rennel's current, which sweeps the Bay of Biscay, and passes out to the S.W. of Ireland, is thought to be a branch of the Gulf Stream by those who maintain its persistency as a current.

These surface conditions have been long known. —Those prevailing at great depths have been very lately revealed to us by the Atlantic dredging expeditions, which have established the existence of a warm upper stratum, a stratum of intermixture, and cold stratum beneath; these are not, however, always at the same depths. There are besides a warm and a cold area within six miles of one another on the floor of the ocean between the Faroe Isles and Scotland at depths of from 500 to 700 fathoms, where the Arctic basin unites with the deeper Atlantic. The temperature at these depths is in the one from 30° to 32° F., and the fauna is meagre and of Arctic character; in the other of 45° to 48° F., with a fauna warm-temperate and prolific. Mineral fragments brought up from the cold area indicate a transport from Iceland or Jan Mayen, while none such occur in the warm area, where the bottom is found to be covered with mud of organic origin, and the lowest forms of life.—It is highly probable that the body of warm water in the Arctic Sea may even reach the pole, and maintain there a sea navigable for a short period in certain summers, entering the polar basin between Spitzbergen and Greenland, and perhaps even up Davis' Strait and Smith's Sound, where the motion of bergs northwards has been observed opposite to the direction of the surface polar-currents of those seas. Lieut. Maury supposes that it runs as an under-current owing to its greater gravity from its superior saltness, and only rises when it reaches far N.; but this view seems very doubtful.

An Arctic cold current visible at the surface sets S.W. down the E. coast of Greenland, being the reflux of the Gulf Stream waters, doubles Cape Farewell, and passes up the W. coast of Greenland, and is probably the same which returns as the polar current down the west shore of Davis' Strait, and passes along the coast of New England and the E. States, inside the Gulf Stream; it chills these shores, and prevents the growth of coral far to S. of its usual latitude, till it is finally lost in the Gulf Stream and tepid waters towards Florida. It is this current which transports so many bergs from Davis' Strait to the shores of Newfoundland, and strews the entourage of the Gulf of St. Lawrence with the rocks of Greenland. A branch of the polar current is said to enter the circulation of the Gulf Stream about 40° W., and another branch further to the S.W. to intersect the Gulf Stream and sometimes to carry bergs as far down as 36° N.

The Brazilian current traverses the entire S.E. coast of S. America, and near Cape Horn unites with an Antarctic drift-current setting N.E. towards the Cape of Good Hope. The rest of the circulating system of the S. Atlantic is due partly to this current and other drifts from the S., and partly to the union of a cold Antarctic current near the Cape with a portion of the warm Agulhas current, which escapes round the Cape, both advancing N.W. under

the drift influence of the S.E. trade. Approaching the limits of the great Equatorial current, it is driven off S.W. and returns upon itself as a counter current; and meeting at the Agulhas bank a current from the Indian Ocean, it is partly deflected with it eastwards, and partly returns into the old circulation.

76. Currents of the Indian Ocean.—The northern portion of the Indian Ocean has various surface drifts regulated by the monsoons. Its main circulation is produced by differences of temperature the same as those already described. Ice in the Antarctic regions advances 1000 miles nearer the equator than in the northern hemisphere; a cold Antarctic



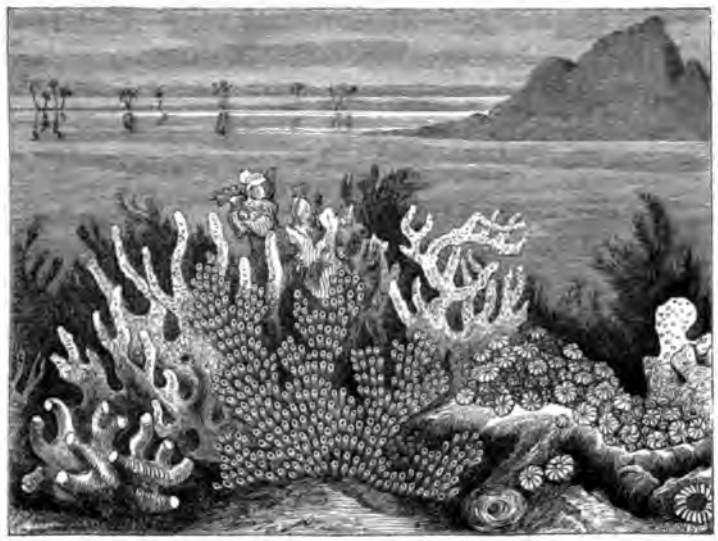
ANTARCTIC ICE.

current has been detected at a great depth in the Arabian Sea, and there is a southern flow of warm water from the equator; but the monsoons and Trades greatly modify the surface movements. An Antarctic drift current deflected by the W. Australian shores, turns W. and suffers a reverse deflection from the Agulhas bank and impact against the Antarctic current of the S. Atlantic. It thus returns upon itself towards Australia in the parallel of 40° S. with a diminished rate of motion. The outer N. portion of it, combining with a monsoon drift, doubles the N. point of Madagascar, and rushes down the Mozambique Channel with a velocity of nearly 6 miles an hour, which off Cape Colony is reduced to 3½ and 3 miles per hour. It is 100 fathoms deep in the Mozambique Channel, and as warm as the Gulf Stream. Off the Cape the main portion of it enters the eastern return current; the rest passes into the Atlantic circulation. Near Kerguelen's Land a minor Sargasso Sea, called Long Kelp, is formed in the central space of the great Antarctic drift-current. The superheating of the equatorial waters, aided by the S.W. monsoon, sends a strong current out N.E. between Papua and Celebes into the Pacific Ocean.

77. Currents of the Pacific.—The currents of the Pacific Ocean are almost a reproduction of those of the Atlantic, save that there is none of them having the grand features of the Gulf Stream. The Antarctic drift-current from lat. 55° S. sends half its stream round Cape Horn; the other passes up the American coast under the names of the Chilian and Humboldt's current, which chill the whole of these coasts, and on reaching near the equator pass off westwards as the Equatorial current, under influence of the forces already indicated. Its W. part near Papua receives the name of Rossel's current, and enters the circulation above mentioned as passing from the Indian Ocean to the N. of this island. The united stream passes the Philippine Islands, and receives thenceforward the name of the Japan current. This current in its breadth of more than 100 miles, in its temperature, which is 86° F., or 12° above the ocean, and in its persistency, resembles the Gulf Stream. It resembles it further in having in the N. part a cold current between it and the land. Passing among the Aleutian Isles it enters Behring's Sea, and having now parted with much of its heat, unites with a cold current from the Arctic Ocean. The joint stream passes down the American coast under the name of the Mexican current, and enters the equatorial circulation. About lat. 50° N. a branch is given off from it towards the west, which forms an inner circulation and a small Sargasso Sea. In the same latitude S. there is a similar inner current, called Mentor's current, whose temperature is 15° F. above that of the Chilian current. Its origin is unknown. Some of the lesser currents will be sufficiently understood by an inspection of the Map.—The theory of part of this subject is still in an unsatisfactory state; accurate observations are wanted on many points, and the forces at play interact in the most complicated manner.

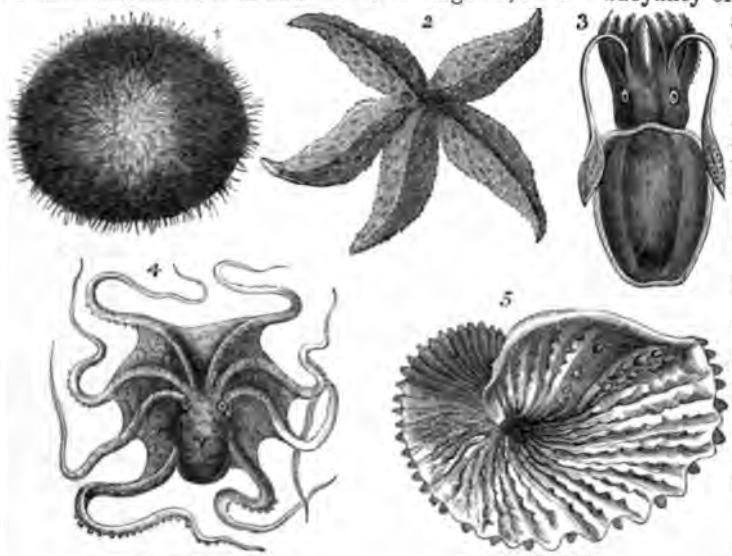
78. Uses—Form of Floor.—The uses of the ocean in connection with the atmosphere as the great equalizer of temperature, and as the source and constant support of a most beneficial, never-ceasing circulation, are among the most interesting facts of physical geography. "All the rivers run into the sea, yet the sea is not full; into that place whence the rivers come thither they return again." In evaporating the surface film gives out its salt, and the exhaled vapour is distributed in all directions over the land. Impinging on cool mountain sides, or mixing with other strata of different temperature, it is formed into fog, mist, rain, or snow. Thus, the waste of summer on Arctic lands and Alpine heights is replenished, and "springs sent into the valleys, which run among the hills; the hills are watered from the chambers of the great and wide sea," and the rivers fed at their sources, or maintained in persistent flow from the ice-caves of snow-

clad mountains. Its currents moderate the extremes of heat and cold; its waters are the highway of nations; "there the ships go;" they are teeming with animal life; "there leviathan disports himself;" "creeping things innumerable, both small and great creatures are there." Myriads of lovely forms



CORAL.

adorn its "coral caves," and its flora is as varied as that of the dry land. If "the channels of the deep were laid bare," and "earth's foundations vast discovered" to us, we should behold an outline almost as varied as that of the continents. The land generally descends with a gradual slope beneath the water to a distance which varies according to the character of the adjoining shore, and then suddenly plunges down to an enormous depth. Thus between Holland and the E. of England, both low and level countries, the German Ocean is so shallow that a rise of 180 ft. would connect them; and no part of that ocean, except a few "pools," is above 300 ft. A like distance off the west of Ireland, France, or Portugal, would give 2000 fathoms of depth. Our section, Plate IX., Fig. 5, represents the floor of the Atlantic, which has been most carefully surveyed for telegraphic purposes. The figures shew that the bottom varies like the surface of a moderately hilly country, where the heights and hollows do not differ more than between 2000 to 3000 ft.; but the slopes between are very gradual. The greatest depth yet found in the entire Atlantic is 2900 fathoms. Life has been found in its depths at 2345 fathoms, where the pressure must be 3 tons on the square inch. Mollusca with conspicuous eyes have been brought up from 1500 fathoms, and from 800 fathoms a cuttle-fish with eyes as perfect as those of fishes; many of the radiata also from vast depths are brightly coloured. The Pacific, in many late soundings, has nowhere been found so deep as 3000 fathoms. The Indian Ocean has a very uniform floor, ranging from 1700 to 1900 fathoms in the deepest parts, and nowhere passing 2200 fathoms. Near the floor the temperature is 23½° F., 43° F. at 1000 fathoms, 50° F. at 500 fathoms, surface 75° F.



RADIATA.

1. Sea-urchin.
2. Star-fish.

MOLLUSCA.

3. Sepia.
4. Octopus or Poulp.
5. Argonaut.

79. Density—Freezing Point.—Fresh water has a point of maximum density at 39°·5 F., thence to freezing at 32° it expands. Salt water has no point of maximum density above its freezing point, which is 27°·5 F.; but if it be cooled below this without freezing, it has a maximum density at 25°·4 F. Salt water in freezing deposits its salt, hence the buoyancy of ice. The Mediterranean and Red Sea are more salt than the ocean. The density of the Atlantic water is 1·026 to 1·027; of Mediterranean, 1·027 to 1·029; of Euxine, 1·0141. The solid constituents of sea water, are soda, potash, lime, magnesia, iron, chlorine, iodine, bromine, silver, ammonia, carbonic, sulphuric, and nitric acids, and 18 others in too small quantity to be estimated. (Thorpe and Morton, *Manch. mem.* 1869-70.) They amount to about 3½ per cent. by weight, or nearly half an ounce to the pound; in the Mediterranean to 3·9 to 4·1 per cent. In the Arctic Ocean and Caribbean Sea shells and corals are seen at 480 ft. of depth; a white plate has been seen at 2796 ft. Objects are seen much deeper by using a glazed barrel.

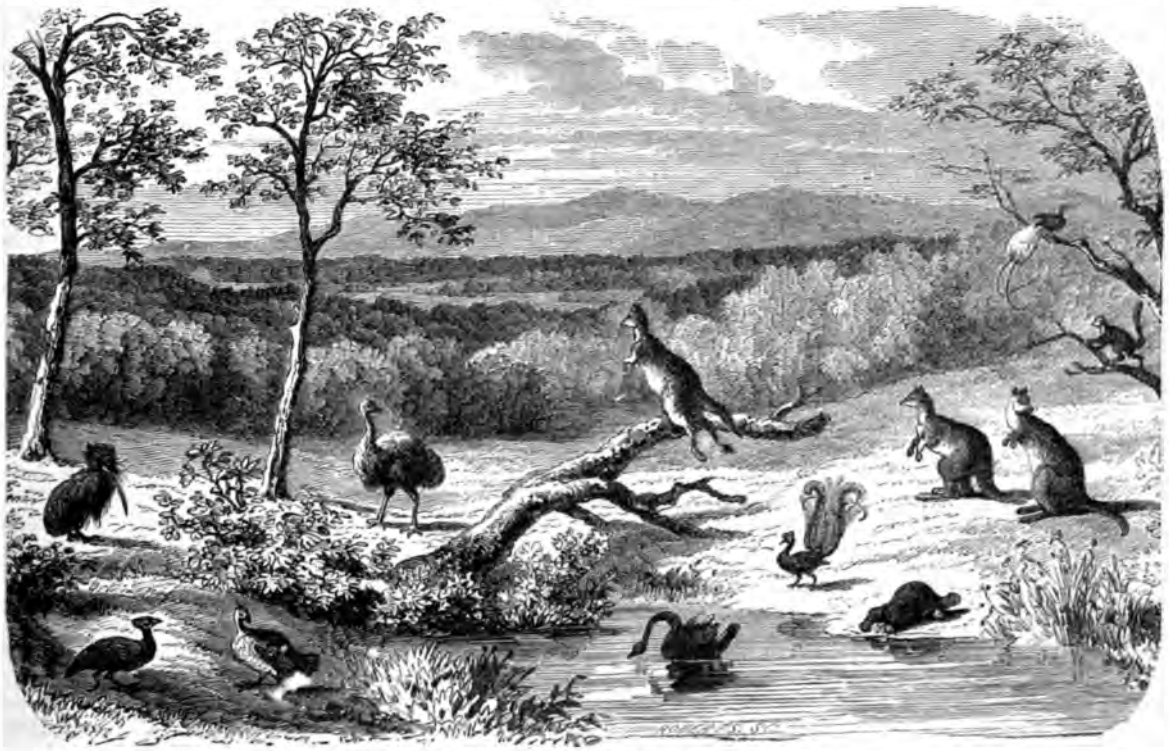
80. Relative Size of Great River Basins.—A glance at the Map will shew what a contrast the Pacific presents to the Atlantic in respect to the number of rivers it receives. This is of course

owing to the close proximity of the great mountain barrier to its eastern shore, and to the small extent of Asiatic coast-line which it washes. The entire areas of all the river basins draining to the Atlantic, is more than double that draining to the Pacific. The drainage area of the Indian Ocean is much less than that of the Arctic. The continental basins are those whose waters do not reach any ocean. The united area of these is more than that of the Arctic basin. These are all distinguished on our Map by separate colours.

MAP XVI.—DISTRIBUTION OF BIRDS AND FISHES.

81. Life Provinces.—In regions of the Earth similarly circumstanced as regards climate, supply of food, amount of human population, and all other outward conditions affecting the existence or development of animal life, the same species do not occur. The land, and, to some extent, the sea also, can be divided into provinces characterized by peculiar assemblages of living creatures, very distinct towards the centres of these provinces, but intermixed towards their boundaries with others which have migrated from the provinces adjoining. There is indeed a certain dependence of animal forms upon conditions of climate and food as affected by distance from the equator and height above the sea-level. But over and above all this, there rules a law of original dispersion of species and groups, which has no relation to light, heat, moisture, drought, soil, or food—is, in fact, independent of all these; and though we may not venture to explain its mode of operation, we can see that it was connected with the first creation of the groups thus found located. That species now absent from certain regions could have existed still if at first indigenous, is proved by this, that introduced there by man they flourish and live on. The diversity is however modified by the operation of a principle in which an obvious design appears: *representative species*, that is species destined to discharge the same functions in the economy of nature, occur in regions widely separated. Thus S. America, which has no sandy deserts, has instead of the camel the llama of Peru, admirably fitted for a beast of burden on the wild and lofty plateaux of the Andes.

82. Birds.—The distribution of birds is much more circumscribed within particular provinces than might be expected from their great locomotive powers; and the same remark applies to fishes, with which we have therefore classed them on our Map. Our notices will be brief, as the facts will be best learned from the Map.



PHYSICAL ASPECT OF AUSTRALIA.

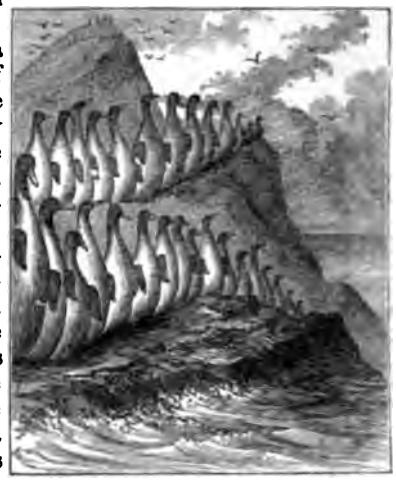
Australia, India, Central Africa, and S. America, present assemblages of families quite distinct from one another; there is no identity of species, though there is a general resemblance among the groups; thus there are parrots in all the four, but not one species is the same. The United States and Europe

have a few species the same; but a great number are found the same in the high latitudes of the two continents, doubtless from the greater proximity of the lands. The large family of the humming birds is found only in America and chiefly within the tropics, whence a few species wander far towards either extremity of the continent. The toucans are confined to tropical S. America; and the passerine group has there 1000 species found nowhere else. The condor, the largest known bird, measuring



CONDOR.

often 16 feet across the wings, is also peculiar to S. America, and ranges from Magellan Strait to the isthmus, which it never crosses, and from the sea-level, where it often feeds, to the snow-line, where its nest is made. Humboldt saw it soaring at the height of 22,000 ft. So peculiarly isolated are the birds of S. America, that they differ more from those of N. America than these do from the birds of Europe. The complete isolation of insular groups is still more remarkable. Out of 26 species of land birds in the Galápagos islands, one only is known in any part of the world. Australia has 320 species of birds, and of these 290 are found nowhere else. A like isolation is seen in New Zealand, 1150 miles distant, whose most remarkable group is that of the wingless birds *(Apteryx)*. The common grouse is found only in the British isles. The penguins, a singular group of water-birds, are limited to the icy shores of the Antarctic lands. Here, on the approach of man, they range themselves in countless numbers, and give battle to prevent his landing. The Arctic lands are occupied by vast numbers of birds of a small number of families.



PENGUINS.

The gallinaceous birds, of which are our domestic fowls, the pheasant, and others, have their native habitation in S. E. Asia; N. America is the habitat of the turkey, but has no other indigenous species of domesticated bird.

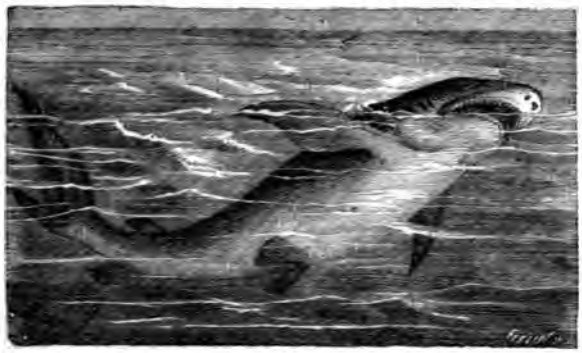
The migrations of birds have little effect on distribution, as they return periodically. A few species of birds have a very wide range. The pelican, wild goose, the swallow, American pigeon, and a few others, range over vast distances in latitude, influenced by climate and the supply of food. The crow is found in all countries except S. America and Australia; the magpie over all Europe. The nightingale from England to Persia; the raven from Greenland to Algeria. — Water-birds have the widest range, and of this order more are common to Europe and America than of land-birds. Some constantly on the wing range over vast spaces, as the petrels in the Atlantic, and in the Pacific the huge albatross, which sleeps upon the wing, and is rarely seen to alight.



APTERYX.

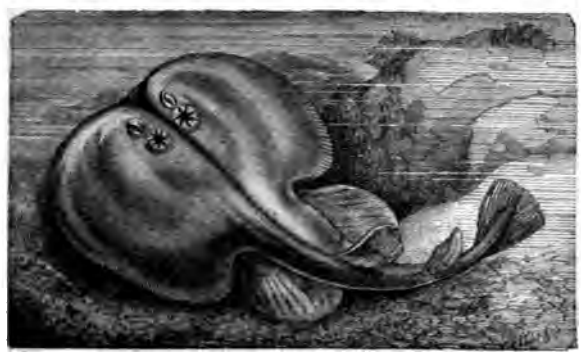
83. Fishes.—The distribution of fishes is less limited than that of birds; they make longer excursions, and are less careful to return. Two Greenland genera, inhabiting very deep water, are found also on the shores of New Zealand and Australia, and, in spite of the enormous pressure,

may have passed between at depths where they found a suitable temperature (Art. 78). The herring and mackerel of the British seas are found also at Magellan Strait. The sharks have their



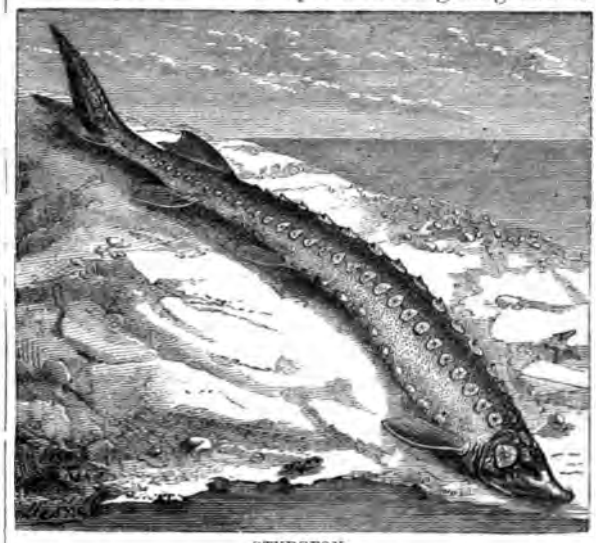
SHARK.

chief development in the tropics, yet some visit the Mediterranean and our own shores, and a few range over the whole Antarctic Ocean. The flying fish are tropical, never passing lat. 40°. A vast zone, 60° broad, in the central Pacific, forms one life province, owing to the great facilities of diffusion presented by the isles, and for transport of eggs by currents; on either side polar forms invade the frontiers. Many species are common to Madeira and the British isles, more than are common to Madeira and the Mediterranean. This sea is a rich province, but except the tunny, the largest edible fish, few are fit for food, from the warmth of the water; it has 444 species of the 643 European marine species; of these 27 belong to the Baltic, and a very few to the Red Sea and Indian Ocean, owing to an old connection across the isthmus. The torpedos belong to this sea; like the gymnotus of the S. American lakes and silurus of the African rivers, this fish has



TORPEDO OR ELECTRIC FISH.

a peculiar voltaic organic arrangement, by which it can give a galvanic shock, and sometimes emit a spark. The Black Sea has a peculiar group of fishes; those of the Caspian differ from all other known species. Here a species of sturgeon grows to



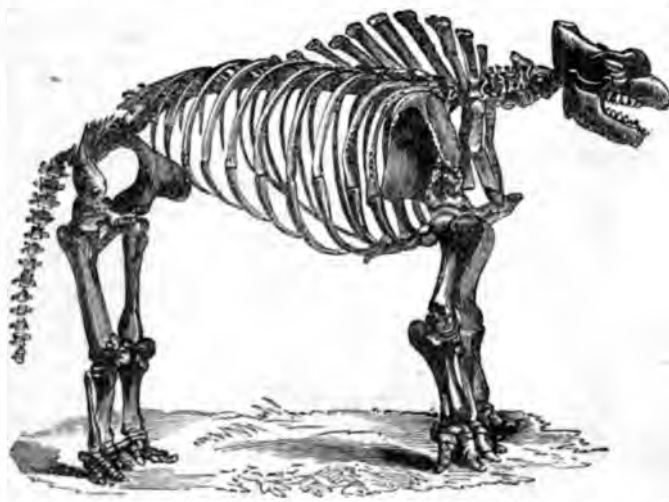
STURGEON.

the length of 25 ft., and weighs 300 lbs.; the best caviare is made from its roe, and the finest isinglass from its swimming bladder. The salmon inhabits both sides of the Atlantic as far as lat. 45° N., the Arctic coasts, and descends from Behring's Strait along both shores, following a cold current (Art. 77). The fish of cold waters, as the salmon, herring, cod, haddock, &c., are greatly preferred for food; when borne away on currents to warmer regions, or when entering a warm current, as the fish of the cold waters inside the Gulf Stream on the American coast often do, the flesh becomes quite unpalatable. The cod-fish thus migrates annually southwards to the Newfoundland banks on the cold current from the Arctic regions. In the same way it enters the German Ocean from the N. The herring comes from the deeper parts of the ocean to the shallows to spawn. Many fine and useful species are borne along on Humboldt's cold Antarctic current; among them is a species representative of the cod. Among **Fresh-water Fishes** a British perch is found in the N. American lakes; the gillaroo trout, having a muscular stomach like a bird's gizzard, is found nowhere but in some lakes in the N. of Ireland. In the class of fishes the range of species is in most cases very limited.

MAP XVII.—DISTRIBUTION OF QUADRUPEDS AND REPTILES.

84. General Conditions.—The limited locomotive powers possessed by reptiles and most quadrupeds have greatly restricted their distribution, and hence we find that in the case of these animals the provinces of life are more clearly defined than in that of birds and fishes. On this account we have placed them together upon the Map; and as height above the sea is another element, affecting the supply of food, and testing the constitution, a diagram is annexed representing distribution in altitude. To this and to the Map we must refer for more detailed information than it is possible to give by any description.

85. Mammalia.—The number and variety of terrestrial mammalia increase from the pole to the equator. This law is reversed for the marine mammalia, which abound more in high latitudes on either side the equator. The following are the *proportionate* numbers for the different zones:—Tropical, 26; N. temperate, 9; Central (S. of 40° S.), 3; Arctic, 7; Antarctic, 0. Viewed on a large scale the great zoological provinces are Asia, Central and S. Africa, Madagascar and adjoining isles, Australia and Papua, Central N. America, and Central and S. America. Europe has no family or order peculiar to it, and is one province with W. Asia and N. Africa. The Arctic regions form properly but one province in all the three continents, the species being either the same or the *forms* very similar throughout. The reindeer and the polar bear range farther than any other quadruped; yet the former once lived in the S. of France. The Arctic musk-ox is American only; most of the others are the same on both continents; but as these mutually separate, the specific differences become greater, till at length, among the groups of mammifers characterizing America, Africa, and E. Asia, there is not a single species in common. Even the Arctic fauna as a whole has scarcely a single species in common with the State of New York, 600 miles to the S.; 600 miles farther, in the Gulf States, there is another assemblage equally distinct, and yet there is no E. and W. barrier to stay migration. The western mountains form such a barrier, and beyond them the mammalia are specifically different. But these contrasts have not always existed in America, for the fossil remains of an elephant, the mammoth (*E. primigenius*), a mastodon (*M. giganteus*), and a horse allied to the common species (*E. caballus*), are widely distributed on the continent. S. America is an extremely rich but most peculiar province. It is remarkable for the preponderance of the edentate order, the almost total absence of pachyderms, ruminants, and marsupials, while the rodents and quadrumana abound. Among 13 species only of the carnivora, the puma represents the lion, and the jaguar or cougar the tiger; the latter is a formidable beast, intermediate between the panther and royal tiger, of which it is a much better representative than the puma is of the king of beasts. The puma has a wider range than any other quadruped, being met with from Patagonia to the borders of Canada, and from the sea-level to the line of perpetual snow on the Chilian Andes. The edentate group characterized S. America in time past as now; the Pampean deposits are filled with remains of animals of this order and of pachyderms now extinct, but with this difference, that in both orders the fossil species were of far larger proportions than the present races; there is indeed no large quadruped in the existing creation in S. America. — Central Africa forms a rich province, with many genera, but no species, the same as in Asia. S. Africa forms a separate province, with the same genera, but no common species. The fauna of Madagascar is perfectly isolated; its most characteristic group is the lemurs, a tribe of nocturnal monkeys with great eyes and fine sense of hearing. N. Africa, W. Asia, and Europe, including the British isles, form a single province with a small number of characteristic genera, but many species quite distinct. India, E. Asia, and W. Malaysia, are perhaps entitled to rank as a distinct province from the occurrence of such peculiar species as the tiger, nylghau, sloth-bear, and musk-deer. Borneo, Sumatra, and Java have a few peculiar genera with much resemblance among the groups; flying quadrupeds are a peculiar feature of the entire archipelago. A profoundly deep channel divides these islands from Australia and Papua, and forms a complete separation of the faunas; so that these, with some small isles adjoining, constitute a province entirely isolated, and characterized by the prevalence of the marsupial type. It has few species in common with the rest of the world; entire families occur which are known nowhere else, and the quadrumana, ruminants, and pachyderms are entirely awanting, while the carnivora are represented by the dingo or wild dog (not certainly known to be indigenous) and four seals. The edentate order has genera of extraordinary structure, the duck-bill and echidna. These unite the structure of mammal, reptile, and bird, and the young of the duck-bill is produced from the egg. The known marsupials are 170 species; of these 138 belong to Australia, 9 to Papua, and 23 are American opossums. Such is the anomalous character of this country, as if peopled by a separate act of creation.



SKELETON OF MAMMOTH.

It is interesting to note the manner of distribution of the several orders of the mammalia. Of the quadrumana, Asia, Africa, and the Indian archipelago, as far as Timour, have 14 genera and 111 species; one inhabits Gibraltar Rock, one the isle of Niphon, their most northern limits in the Old World, but they are found fossil in the English tertiary beds. The platyrhine or New World monkeys form 9 genera and 91 species, all in S. America, except one or two in Mexico. The most



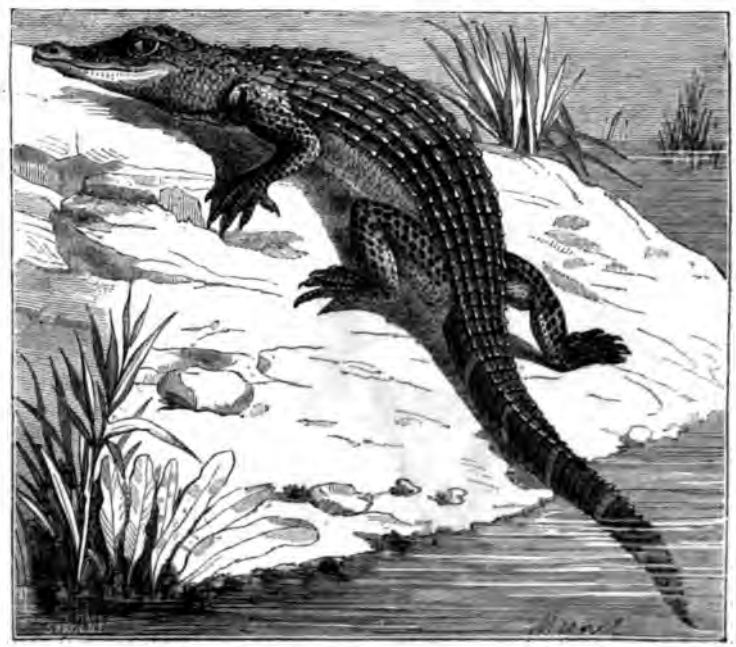
PREHENSILE-TAILED MONKEY.

remarkable group is the sapajous or prehensile-tailed monkeys. Of the carnivora, Asia and Europe have 166 species, Africa 130, tropical America 109 (S. America 13), Australia 7 (4 seals, 2 bats, and 1 dog). The tiger is limited to S. E. Asia; the lion is found in N. India, parts of Persia, and all over Africa, except the desert and Egypt. The pachydermata abound in the Old World; the New has 1 tapir and 2 peccaries (dicotyles), in S. America. Of the edentata, S. America has 3 times as many as the rest of the world. Of the rodentia, half the number of species belong to America; the other half to the Old World. There are in America alone 77 species of porcupine, while the Old World has only 6. Of the ruminantia the Old World has 2 species of camel, 7 of musk-deer, 37 of deer, 2 giraffes, 47 antelopes, 18 of goats, 25 of sheep, and 18 of oxen. The New World has 4 species of llama, 14 of deer, 1 of antelope, 2 of the sheep, 2 of the goat, and 2 oxen. Australia has neither ruminant nor pachyderm.—For maurspials, see above. Of this order there are fossil species in the English oolite. Of the cetacea the great majority inhabit the polar seas; but the Orinoco has the lamantine, and the eastern seas the dugong.

Almost all continental islands, except Madagascar, have the same quadrupeds as the adjoining mainland, or have had in time past, their separation being subsequent to the diffusion of the animals from some specific centre. Thus the elephant, rhinoceros, tiger, &c., inhabit Sumatra; the elephant, rhinoceros, hippopotamus, hyena, bear, &c., formerly inhabited Great Britain; remains of the giraffe, elephant, hippopotamus, &c., have been found in Malta, Sicily, and Greece; at present the depth of water between Sicily and Africa is only 37 to 60 fathoms. Mammalia often disappear also without geological revolutions. Thus the lion inhabited S. Russia in the time of the Roman emperors; the beaver, bear, boar, and wolf have recently become extinct in Great Britain; the Irish elk, found fossil in Ireland, England, and the Isle of Man, most probably co-existed with man. At present an elevation of 200 feet would connect the Mull of Galloway to St. David's Head, and one of 280 ft., Carnarvon to Wicklow.

86. Pelagic Isles never have large native quadrupeds, and very rarely any; if any they are of peculiar species. New Zealand has one small rodent; the Galapagos, one species of mouse, supposed to be distinct; the Falkland isles have a blue fox, drifted on ice from Patagonia; Iceland has only the Arctic fox, brought, no doubt, in the same way, and a mouse which steers itself by its tail across rivers. A rat, a few bats, the dog and hog, are the only mammifers of the Pacific isles, and these have either been introduced by man, or have made their way from New Guinea, passing from group to group of the scattered islets.

87. Reptiles.—The same laws of distribution hold in regard to the reptile class. Half of the whole number of known species are American, but not one of these is found in any other part of the world. The species of N. and S. America are distinct, but they intermingle in the Columbian archipelago. If we represent the number in America by 8, then Europe and Australia have 3 each, Asia and Africa 5 each. The boa of America is distinct from the python of India, the rattlesnake is American, the cobra-de-capello Asiatic, the cerastes African. Java has 56 species of serpents; not one has yet been found in Borneo. Japan has 6 species, none of which exist elsewhere. Australia has 83 species, the bite of most of which is dangerous; 23 are quite harmless; 15 are sea serpents; all the species are



ALLIGATOR.

peculiar, except the sea snakes. Tasmania has three species, all venomous. There are none in New Zealand. The Pacific isles have no reptiles of any kind except the Marianne group. The saurians of the Indian rivers and those of Africa and America are all specifically distinct. The crocodile of the Old World is represented by the alligator or cayman in the New. The dragons are flying lizards. The chameleon of the Old World is represented by the anolis of the New. The land and fresh-water tortoises number 61 species, the chelonians 8. Africa has more of the former than all the rest of the world; a peculiar group of chelonians inhabits the shores of the Galapagos, where they grow to an enormous size, 500 to 600 lbs. weight, and are ridden about by the sailors who call there. A group of lizards, having both lungs and gills, inhabit the lakes in the caves of Carniola and the great cave of Kentucky; they are distinct species, and are all perfectly blind, having either no eyes, or the organ in a rudimentary state and undeveloped.

MAP XVIII.—DISTRIBUTION OF PLANTS.

88. General Influences. — The distribution of plants is chiefly determined by temperature; moisture is rather a secondary cause, as mainly dependent on temperature. The nature of the soil has an influence also, but this is less understood. Now temperature varies with latitude and altitude, so that the same conditions, in a general way at least, are given by elevation above the sea-level, even in tropical regions, as by distance from the equator. The climatal zones, as marked by the isothermal lines, are distinguished by peculiar assemblages of plants; and a mountain slope within the tropics, from the sea-level to the line of perpetual congelation, may be divided in the same way, and exhibits a similar change in the grouping of its plants as that which is observed in passing from the equator to the frozen regions about the poles. But the distribution of plants obeys another law which has but a subordinate relation to such conditions, and which ruled, in some mysterious way, over the first peopling of the different regions of the Earth with all its living species. The distribution of plants thus ranges itself under three heads—in latitude, in altitude, and in longitude.

89. Distribution in Latitude.—In relation to latitude, vegetation may be distributed into 8 zones:— 1. The *equatorial*, bounded by the isotherm of 79°·3 F., to about lat. 15°, the broader part of it being on the N. side of the equator (Art. 54). Its limits vary with the inflections of the isothermals,



BAOBAB TREE.

and portions of it are several degrees above the mean (Art. 56). The vegetation is vigorous, beautiful, and luxuriant, especially where the maxima of heat and moisture prevail, as in the Amazon's basin, Senegambia, and the Indian Archipelago. The Old World deserts and the American llanos are of course exceptions (Art. 65). The most conspicuous groups of this zone are the palms, banana, ginger, arrow-root, the baobab and silk-cotton trees, arborescent grasses, and the magnificent *Victoria regia* lily of Guiana, and the rafflesia of the Indian isles, whose flowers are 3 ft. in diameter. The forests are magnificent, with a prodigious growth of underwood and parasites. 2. The *tropical zone*, reaching the tropics and the isotherm of 72°·5 F. The vegetation wants the imposing grandeur of that of the first zone, except in a few favoured spots; the forests have a less undergrowth and fewer parasites, and the chief groups are the pepper tribe, tree-ferns, convolvulus, and melastomas. 3. The *subtropical zone* reaches the isotherm of 68° F., and to about lat. 34°. The myrtle, laurel, magnolia, and forest trees with broad, shining, leathery leaves, prevail, and a few tropical forms are still found. 4. The *warm-temperate zone* reaches the isotherm of 54°·5 F. and lat. 45°, but with an irregular outer limit; the palm is absent or dwarfed, and the chief forest trees are the cork, oak, beech, and chestnut; tree-ferns in New Zealand, heaths and azaleas, cisti, and many leguminosæ are the other forms. 5. The *cooler temperate zone* extends to lat. 58° and isotherm of 41° F.; the forest trees have small flowers and deciduous leaves, except the few coniferæ, and they nourish lichens and mosses. There are fine grass pastures, many annuals; and hop, ivy, honeysuckle, and other familiar groups abound. In the southern hemisphere, Patagonia alone represents this zone. 6. The *subarctic zone* reaches the polar circle and the isotherm of 36°·5 F. in September; the prevailing features are grass pastures, forests of coniferous trees, birch, willow, and alder woods, and showy annuals. 7. The *arctic zone* reaches the isotherm of 41° F. in July; it has dwarf shrubs of creeping habit, as rhododendron, andromeda, bog-myrtle, with cotton grass, sedges, mosses, and lichens. 8. The *polar zone* embraces the lands about the N. pole, and the chief plants are herbaceous but of dwarf habit, as saxifraga, pyrola, dryas, a few ranunculi, cochlearia, dwarf salix, and some peculiar genera, as *parrya*,

eutrema, phippsia, and *colpodium,* not found on Alpine heights in more southern regions; the lichens surpass in numbers the flowering plants. In this zone and the last the state of the surface immediately preceding that which now exists was extremely different; a prolific vegetation flourished in which were present forms now only found 15° to 30° farther from the pole.



COTTON PLANT.

90. Distribution in Altitude.—A division into 8 corresponding regions of altitude seems to rest on a natural foundation:—1. Musaceæ (banana) and palms, sugar cane, coffee, and cotton, arums and orchids; the ginger tribe vanishes at the upper part. 2. Region of tree-ferns, figs, and melastomas. 3. Laurels and myrtles, acacia and eucalyptus trees, magnolia, camellia, and heaths. 4. Evergreen trees, olive, and arbutus, convolvulus, geranium, and other showy flowers. 5. Region of deciduous trees, as in the cooler temperate zone, oak, beech, &c. Here at 5000 ft., in California, flourishes the king of the forest, the gigantic Wellingtonia pine, which reaches 450 ft. in height and has a diameter of 29 ft.



WELLINGTONIA PINE.

6. Region of conifers, reaching 9500 to 11,500 ft. on the equator, and on the Alps to 6500 ft. 7. Region of Alpine shrubs and vegetation, as in the arctic zone. 8. Region of Alpine herbs, mostly perennial, with blue or yellow flowers, mainly disposed in patches; chief genera, gentiana, primula, dryas, draba, viola, salix, and carex. The last traces of vegetation are a lichen, *lecidia geographica,* on bare rocks, and an alga, *protococcus nivalis* (red snow). On the Alps the zones of vegetation are as follows:—the orange, olive, and fig reach about 950 ft.; the vine ceases at 1600 ft.; cherry, walnut, and chestnut at 3100 ft.; wheat at 3600 ft., oats at 4900 ft., barley at 5100 ft.; the alder, ash, elm, oak, and yew reach 4500 ft.; the beech 4800 ft.; pine and larch 6500 ft. Above the forest zone are the rich "alps" or pastures; two rhododendra and a dwarf heath flower on the edge of the perpetual snow; and on bare spots on the Mer-de-glace (le jardin), on the Matterhorn and M. Blanc at 11,509 and 11,382 ft., a saxifrage, a geum, pedicularis, aretia, and others, are found in flower.

91. Distribution in Longitude.—This distribution is analogous to that of animals into provinces, and of these about 25 are made. The higher orders are more limited in range; the cryptogamic class, whose sporules are impalpable powder, the most diffused; and as a rule, if the same species are common to remote provinces, they are found in the intermediate space. This remote correspondence seems due to causes which acted before the surface was broken up by geological revolutions, or may still be acting through various means of transport. Australia has 4166 species, of which 166 are found in Europe, and these are mostly cryptogamic; the forest trees are all evergreen; it has no fruit tree of any kind, nor edible vegetable; yet these are now introduced and flourish, as do the vine, cotton, and tea plant, tobacco and mulberry, fig and orange. There is no heath; this tribe belongs almost wholly to S. Africa; America has none; it is represented there by the azaleas, in Australia by the epacridiæ. Of 3000 species of flowering plants in the United States, only 400 are known in Europe; America has all the cacti (Indian fig) except 2 or 3 species; the mountain region of S. America has only 24 species found in any part of the Old World, and these are grasses and sedges; but the plains have many species found also in Africa. As the Old and New Worlds approach, the species become more like; the species common to both are found also in the Aleutian isles, which connect the continents. Pelagic isles have a peculiar flora, and are poor in species. Thus,



TOBACCO PLANT.

St. Helena has 30 flowering plants, of which only one or two are found anywhere else; but out of 60 cryptogamic, 48 are found in other regions. The flora of the Galapagos is perfectly distinct, but has a S. American type. The New Zealand flora is very peculiar, but blends in some forms with Australia and the Pacific isles; the difference in the abundance of ferns, some of which reach 40 ft. in height, being caused by its superior moisture. The far scattered isles of the Pacific and Southern oceans have many common species, the nearest continent influencing to some extent the floral type. For a like reason the marine vegetation, more subjected to transporting agencies, presents a greater intermingling of provinces than does the flora of the land. There are, however, many cases of very wide range among land plants, which no theory of diffusion can explain; such as the occurrence of many British species on the Falkland isles, *e. g. primula farinosa* and *cardamine hirsuta*, and of many N. European species on the Himalayas, as the gooseberry and currant tribe.



TREE-FERN.

92. Cereals and other useful Plants.—The distribution of the cereals has been influenced more than that of any other family by the agency of man; and their adaptability to various climates has exercised a reflex influence on the distribution of the human race. All of them belong to the family of the grasses. The principal are wheat, maize, rice, millet, spelt, rye, oats, and barley. Wheat, barley, and spelt (*Triticum spelta*) are native in the W. of Persia; maize is indigenous to America; rice in E. Asia and America; the native countries of oats, rye, and millet are unknown. Rice, maize, millet, and occasionally spelt, are the grains of tropical countries, though wheat is grown in many places within the tropics in winter, as in lower Bengal, where rice is the summer crop; oats, rye, and barley of cold countries, or of high countries in low latitudes, as in Peru, where they ripen at 10,000 or 12,000 ft. Rice reaches as far N. as the plains of Lombardy; maize is grown in the valley of the Rhine as far N. as lat. 49°; wheat succeeds best on the borders of the subtropical zone (No. 3.), and is of no value further N. than lat. 60° in Europe, and 46° to 55° N. in N. America (see Art. 37). The limits of the grain crops are marked upon the Map; and by means of ten shades of colour we have shewn the regions within these limits where the different kinds are cultivated. In central Asia (Art. 24), in Siberia, and parts of the N. of Europe, where the cereals will not grow, food is supplied by the growth of the quinoa (*chenopodium quinoa*) and buck wheat (*Polygonum fagopyrum* and *P. tataricum*).



RICE.

The **Potato** (nat. ord. *Solaneæ*) is a native of S. America, and was found under cultivation on the Andean plateaux. **Cassava** is a starchy root of a tall, succulent shrub (*Euphorbiaceæ*), and is tropical in both worlds. **Arrow-root** is the tuber of the maranta, an herbaceous tropical monocotyledon (*Marantaceæ*). The **Plantain** or **Banana** (*Musaceæ*) is a gigantic tropical herb, a spathose monocotyledon, reaching lat. 30° and 5000 ft. of altitude near the equator; its fruit is a large pod or capsule with a nutritive flour; the produce of a given area is 25 times greater than that of wheat. Indian muslin is made of the fibres of its leaves. The **Breadfruit** tree (*Artocarpeæ*), to which the fig also belongs, is a tropical dicotyledon, whose fruits and nuts are highly prolific. The **Tomato** is of the same family as the potato. The **Tea** plant (*Camelliæ; thea*) is a native of the S.E. of Asia, a member of the well-known group of camellia. The **Coffee** plant (*Cinchonaceæ; coffea*) is a shrub 6 to 12 ft. high, a native of N.E. Africa, hence taken to Arabia, whose seeds are the coffee bean. The **Vine** (*Viniferæ* or *sarmentaceæ; vitis*) is a climbing



BREADFRUIT.



TEA PLANT AND COFFEE PLANT.

dicotyledon with tumid joints and stipulate leaves, a native of Armenia or Persia. America has a native species, the catauba vine. The **Sugar Cane** is a species of reed *(Gramineæ)*, and is a native of E. Asia. The **Orange** *(Aurantiaceæ; citrus)* is a dicotyledonous tree or shrub, a native of the E. Indies. The citron, lime, and lemon belong to the same order. The **Cotton** plant (*Malvaceæ* or mallow tribe) is a herbaceous or shrubby dicotyledon, and the cotton of commerce is the hairy covering of the seed of several species of *Gossypium*. It is a native of the tropics in several countries, and there are two principal varieties, long staple or sea-island, and short staple or upland. The **Olive** is a dicotyledonous tree or shrub *(Oleaceæ*, to which the ash and lilac also belong), a native of N. Africa and W. Asia; the oil



SUGAR CANE.

is contained in the pericarp, not in the seed, as in most other plants. The **Pepper** tribe *(Piperaceæ)* are achlamydeous dicotyledons, closely allied to monocotyledons, shrubs or herbs, native in tropical America and the E. Indian isles. The **Ginger** tribe *(Scitamineæ)* are tripetalous monocotyledons, with spiked or spathose flowers, herbaceous, natives chiefly of the E. Indies, but some are found on the two other continents. The **Nutmeg** tribe *(Myristiceæ)* are apetalous, dicœcious trees, found only in the tropical regions of India and America.

MAP XIX.—DISTRIBUTION OF MAN.

93. General Conditions.—The distribution of man over the surface of the globe is analogous to that of animals in this respect, that the different varieties occupy distinct regions or "provinces," and are intermingled along the boundaries. There are, so to speak, centres of maximum development, and the characters become less marked, and the races more assimilated, as we retire from these centres. But there is this remarkable difference compared with the distribution of animals—all mankind form but one species, sprung from a single pair; and the different races are mere varieties, which must, therefore, have been in some way brought about in time by the action of natural causes. What these were has never been determined; and various conjectures have been framed regarding their nature. The most probable seems to be the effect of climate and food, and the maintenance of a separate or exclusive state of society for a long time; after that, in their migrations, or in their "dispersion," the earliest tribes parted one from another, and went to people different regions. We know that though man has a constitution extremely flexible, adapting itself to almost every clime, and can subsist on food the most various, yet it is not with impunity that a great change of conditions is undergone. Thus the climate and food of India soon tell upon the health of Europeans, and render necessary frequent returns, or a sojourn in sanitaria among the mountains; and it is impossible to rear there the children of European parents. The Anglo-American race has been already essentially modified. Such influences affect thousands of persons at the same time, and not slowly by derivation from one.

Viewing facts, then, of this class in the light of history and recent experience, we can hardly doubt that the varieties of man which now people the earth were produced in the way above indicated; and some of them may even have been brought about in so brief a space as a few centuries. That some of our existing varieties were established at an early period we know from Egyptian monuments 3000 years old, which shew the features and colours of the Persian, Jewish, and Negro races. But as these and other varieties were so early established, and have remained permanent through so long a period, we must suppose either that the causes of change have ceased to act with the same energy as in times long past, or that the estimate we have formed of man's age upon the earth is erroneous. The latter is the most probable supposition.

Recent geological discoveries point in this direction; and the statements of our most ancient and revered Record are not so explicit as to enable us to deduce from them an exact chronology. Man may thus have existed much longer on the earth than has been hitherto supposed, and a much longer time may thus be put at our disposal for the growth of the various forms of speech, and the modification of the offspring of one original pair into the various races, of which three at least have had their existence for 3000 or 4000 years.

94. Varieties of Man. — The several races or varieties of man shade off gradually into one another, and the data on which we must proceed are of two distinct kinds, so that classification is difficult, and many systems of distribution have been proposed, none of which can be considered wholly satisfactory. One class of data has reference to physiological differences, such as the form of skull and limbs, the colour of the hair, eyes, and skin; another is obtained by observing similarities of language, cognate roots and points of analogy in grammatical structure. But our knowledge of both is as yet so imperfect, that we cannot look to either as a certain guide; and as they are quite independent, they often point in different directions. The science of comparative philology enables us to form separate families of speech, to trace certain languages back to a parent stock, and to assert the existence of unquestionable affinities between the dialects of peoples whose divergence from the same source cannot be proved from history. But identity or affinity of language is not conclusive evidence of blood relationship, since tribes and even nations have often (mostly by conquest) lost their own language, and have come to speak that of another people; and of the languages of many tribes and nations we know as yet so little, that we cannot pronounce upon affinities, much less use these in classifying such peoples. Observations on the comparative physiology of the races are so imperfect and limited, that they form no safe basis for classification. The influence of climate, food, and other modifying causes is still obscure; and naturalists are not agreed on the criteria, anatomical or physiological, to which the chief importance should be attached. Hence it is that all our generalizations as to the grouping of races must be considered as merely tentative; and it is only as respects certain very broad similarities, and certain local areas, that we can feel confident in the results which have been reached.

I. The race to which we apply the name of Aryan or Indo-European, is one whose identity we are entitled to assert solely upon linguistic grounds, for among its branches there is much diversity of physical characteristics. At the dawn of authentic history, we find these peoples spreading from the Ganges to the Atlantic, over Northern India, Persia, Afghanistan, parts of Asia Minor, and the greater part of Europe. Within the last three hundred years, they have occupied North and South America, expelling the primitive inhabitants from nearly the whole of the temperate parts of the former continent, and from most of the coast districts of the latter. The name Aryan has been taken from a word which appears in the old Persian tongue, applied by the people to themselves as distinguished from the inhabitants of Turan —the steppes of the Oxus—and which is also the source of many words in Greek, German, and other languages of the same group. The chief subdivisions of this great group are the following:—

(1.) The Hindoo, occupying Northern and Central India, and parts of the mountainous region to the N.W. of India, mixed in many places with aboriginal tribes speaking some Turanian language.

(2.) The Persian, occupying the country E. of the Tigris and N. of the Indian Ocean. The early language of this division—the Zend—is the source, as well of old Persian as of Median, and of most of the dialects spoken over the country S. of the Caspian



HINDOO.

as far as Beloochistan. The Armenians may be classed here.

(3.) The Italo-Hellenic, or so-called Pelasgic, including the ancient Greeks and Macedonians, most, if not all, of the peoples of Italy, the Sicels of ancient Sicily, and probably the Carians, Mysians, and several other races of Asia Minor.

(4.) The Teutonic, including the Goths (whose language is the earliest form of German known to us), and, among modern peoples, the High Germans of Central and Southern Germany, the Low Germans on the coast of the North Sea and on the Lower Rhine, the Danes, Norwegians, and Icelanders (whose language approaches more nearly to Low than High German), the Swedes, and the English, who are substantially a branch of the Low German race, with some admixture of Keltic and Scandinavian blood.

(5.) The Keltic, including the Gauls of modern France (who exchanged their aboriginal language for Latin in the second and third centuries of our era), the Welsh of Wales and Cornwall, the Irish, the Scotch Highlanders, and the inhabitants of the Isle of Man.

(6.) The Sclavonic, of whose two leading groups the one includes the Russians, Serbs, Croatians, and the inhabitants of the N.E. coast of the Adriatic,

while the other consists of the Poles, the Czechs of Bohemia, the Slovaks of Northern Hungary, and some less conspicuous tribes. The Wends of the Baltic coast probably belonged to the same group.

(7.) The Lithuanian, including the Letts and cognate tribes of E. Prussia and W. Russia (Lithuania), whose language has preserved a closer resemblance to the supposed aboriginal tongue of the Aryan race than any other except Sanskrit and possibly Zend.

Nearly the whole of Europe is occupied by branches of this great family. The only non-Aryan tribes settled in it are :—

The Turks, scattered thinly over European Turkey, who speak a Turanian language, and migrated hither in the fifteenth century from W. Asia.

The Magyars or Hungarians, who (intermixed with the Sclavonic races) occupy Hungary and part of Transylvania, and who passed into the Danube valley in the ninth century, coming, like the Turks, from the plains beyond the Sea of Aral.

The Finns, whose language is allied to Hungarian; and the Lapps, speaking a Turanian tongue, whose affinities are imperfectly known.

The Basques of Bearn and Biscay. Their language is certainly not Aryan, and it has therefore been plausibly supposed that they are the sole surviving representatives in Europe of the primitive Turanian population, which probably occupied much of it before the arrival of the Keltic and Teutonic peoples. The Iberians of ancient Spain may probably have also belonged to this stock.

The Bulgarians are a Sclavonic people, but there remain several other peoples whose place in our classification is still matter of controversy: the Wallachs or Roumans of the Danubian principalities, who speak a language derived from Latin, but of whose origin little is known, and the Albanians, a discussion of whose ethnological affinities would lead us into details for which there is no space in the present sketch.

II. The second great family, the Semitic, is also classed as such on philological grounds, all the languages spoken by its members presenting a close similarity in their roots and their grammatical system. To this family belong the Arabs, Jews, ancient Phœnicians and Assyrians, and many minor tribes of Asia and N. Africa, including some at least of the peoples of Abyssinia.

Physical and intellectual qualities of the highest order, capacious, well-formed heads, a well-proportioned and robust frame, and great personal beauty, have in all times distinguished the Aryan and Semitic races; they have always shewn an aptitude to lead and command, and have been dominant in all countries where they have arrived.

III. The so-called Turanian races do not form a family in the same sense as the Aryan or Semitic; the family is little more than the name of a residuum into which philologists throw those languages which cannot be referred to either of the other two great groups; and Allophylian is perhaps a better name than Turanian, as it less suggests an identity of origin or a close relationship.



ESQUIMAUX.

This race occupies a vast territory, comprising the central, southern (except Malaya), eastern, and northern parts of Asia and the Arctic shores of



ARAB.



CHINESE.

Europe and America, and embraces a great variety of nations—the Tibetans, the people speaking Tamil and Telegu in S. India, and the hill tribes of various districts; the people of China, and Japan, the various Tartar tribes, the Samoiedes, Finns, Lapps, and Esquimaux. The most extreme forms, as the northern Chinese and Kalmucks, are distinguished by a yellow or sallow olive complexion, straight, coarse, thin hair, scanty or no beard, a square, broad cranium, low forehead and broad face, small nose, high cheek-bones, and small eyes set obliquely; even in the best-developed families of this race the



CHINESE LADY.

stature is small, with broad shoulders and short neck. As a rule the race is not remarkable for personal beauty; yet some very beautiful women are found among the Chinese, Japanese, and Tartars, especially those of the high Steppes; the fairest in complexion are found among the people of Tibet, as in other cool climates. Among the highest branches of the family may be named the Magyars of Hungary, the Finns, and the Turks. The language



RED INDIAN.

of the Indo-Chinese, Chinese, and Japanese is monosyllabic, and of most singular structure. The languages of the other nations have but a slight resemblance.

IV. The American variety of the human race has more analogy with the Turanian than with any other, the connecting link appearing to be the Esquimaux of the Arctic regions. Through the Chinooks and Athabascans the change is scarcely perceptible, and these pass gradually into the Red men of the central regions. These again merge into the Mexican and S. American races; and there can be now little doubt, as well from physical characters, form of skull, intellectual capacities, and affinities



RED INDIAN GIRL.

of language—the grammatical structure being somewhat similar in all, though the vocabularies differ—that the whole continent has been peopled by one race.—Among themselves there are many varieties between the almost black inhabitants of Lower California and the fair races of the high mountain plateaux; but the same occurs in the case of the other races of men, and has a manifest relation to climate, food, and social habits.

V. The Negro race is located in Africa, S. of the Sahara desert, and is found in its most typical forms



NEGRO OF BORNEO.

on the hot S. western plains and river deltas. In these the skin is black and shining, the skull is compressed and elongated, the jaws project, the forehead is low and retreating, the cheek-bones prominent, the nose flat and broad, the hair is short, black, soft, and curly like wool, the beard is scanty or wanting; but there is great diversity in the different regions of the continent. The Gallas on the Abyssinian frontier, the Soudan nations, and many Nubian tribes approximate to the Mongolian or Semitic type; they are of a dark brown colour, of fine vigorous frame, full of intelligence and energy, dominant and aggressive in their character, and in religion Mahometan. The Gallas and Denkas of the Nile valley approach nearest to the Coptic tribes, the ancient ruling race in Egypt; and thus a link may perhaps be formed between the white and



NEGRITO.

black races. It is also remarkable that in mountain districts and high dry plains the negro form and features are greatly modified, approaching the same type. From this cause, and probably also by intermixing with a Malay emigration from Madagascar, the Kaffirs of the south differ much from the negro type.

It seems to be now agreed among physiologists that there is no organic difference between the skin of Europeans and that of the coloured races. The colour in all of these is produced in the same way as the abnormal discolorations which take place in the skin of Europeans. These all depend upon the development of minute granules of a dark pigment in cells between the outer skin or cuticle and the cutis or second skin. These pigment cells are produced even in the case of lentigo (summer freckles).

VI. The Negritos or Oriental Negroes of Australia and Papua form a group more nearly allied to the African than to any other; and it is said also that their languages have some affinity. Their colour is nearly black; but in Australia the hair is not of the same wool-like structure as in the true negro; it is long, lank, and unfrizzled; and in physical qualities they are inferior to the negro. In N. Australia, and in Papua, there is a close approach to the African type; it was the same in Van Diemen's Land before the race became extinct; in Australia the race is rapidly disappearing. From their isolation, perhaps, they are lower in the scale of intelligence and



AUSTRALIAN.

civilization than other negroes; those of Australia indeed are said to be the most miserable and degraded of the whole human family. Whether the Oriental negroes are a colony or a race originally varied in their present seat, it will be impossible to determine till the languages have been more carefully compared. There is an outlying family of this race, the Mincopies and Andamaners, in the island groups of the Bay of Bengal; and another in Central India.

VII. The Malay variety had its first seat in the S. of the Malay peninsula, and has spread to Madagascar on the W. and Formosa in the N.E. through the great islands of Malaysia. They seem to have



MALAY.

a closer affinity with the Turanian race than with any other; they have fine physical qualities, great courage and daring, and are not incapable of considerable progress in civilization. The colour is olive, brown, or yellow. Long given to piratical practices in the Eastern seas, they may have been driven by stress of weather to Madagascar, 3000 miles across an ocean without a single intervening island, and have settled in it, unable to find their way back; there are remnants of another race, however, allied to the Polynesian blacks.

VIII. The Polynesian Malays occupy the scattered islands of the Pacific, from New Zealand to Easter isle inclusive, and have unquestionably undergone modification, no doubt from oceanic influences. In some of the islands they have little of the Mongol or

Malay aspect, are much more handsome, have fine brunette complexions, beautifully formed limbs, and differ from Europeans merely in the wider nostril



POLYNESIAN.

and thicker lip. They have been found capable of considerable culture; and even among the most savage of the islanders, a great revolution has been wrought since their acceptance of Christianity. All the languages have the same grammatical structure, though their vocabularies greatly differ; but too little knowledge has as yet been gained in regard to the structure and affinities of these languages to enable us to generalize safely.

94. Density of Population.—On a small separate Map an attempt is made to indicate the comparative density of population, but it is difficult to give details by shades. The density is greatest in the island of Bermuda, where there are 477 persons to every square mile. Next is Belgium, 438, where cultivation is by the spade and hoe, and 43 per cent. of the farms are under 1¼ acres; next is China proper, 288; Netherlands, 275; Great Britain and Ireland, 245; Japan, 233; Massachusets, the most dense in America, 157; United States generally, 11·3; S. America, 4·03; Iceland and Faroe isles, 1·8; basin of the Amazons, 1 person to 10 square miles; Patagonia, 8 persons to 100 square miles; Greenland, 1 person to 100 square miles.

96. Religions of the Globe. — A second separate Map shews how small is the area yet possessed of the highest civilization!—The people professing the Christian religion number about 355,000,000; those professing the religion of Mahomet, 120,000,000; and those attached to one form or other of heathenism, 733,000,000.

MAP XX.—GEOLOGY OF THE BRITISH ISLES.

97. The geological structure of the British Isles is so typical of that of the whole globe, that there are very few members of the entire series of rock formations that do not occur with us. The series as developed in these islands is given in the reference scheme upon our Map, embraced in three classes: —1. The palæozoic formations, containing the records of the old life of the globe, which extend from the fundamental azoic rocks to the top of the coal formation; 2. The mesozoic rocks, ending with the chalk, whose fossils represent a middle or intermediate life period; and, 3. The tertiary or cainozoic, in which the existing forms of life first begin to appear. — The older formations, hard, crystalline, and enduring, impress their marked physical aspects on all the mountain tracts of the three kingdoms. The newer formations, soft and incoherent, give their smooth and flowing outlines to the plains and dales.

According to the order of mineral succession indicated on our Map, the base of the entire geological series in these islands is the granitic gneiss of the Hebrides. This rock (No. 16 of the Map) occupies the whole of the Long Island from Barra Head to the Butt of Lewis, and a narrow tract on the N.W. coast. The strike is usually N. of W., and the strata either vertical or dipping to the S.W. or N.E. Bosses of granite rise through it, and it is everywhere penetrated by granite veins, as if underlaid by a great body of this rock, or as if once flanked seaward by a broad granite band now washed away or sunk down. The gneiss consists of quartz, felspar, and hornblende, the quartz being often in very small quantity, and mica often replacing the hornblende, or occurring with it in occasional scales only. Thus the main ingredients are felspar and hornblende. The upward succession is represented on the annexed diagrammatic section (Fig. 21). On the highly inclined beds of gneiss



Fig. 21.

(*a*), a sandstone (*b*) rests unconformably in nearly horizontal strata, conglomerate in the lower part, but upwards sub-crystalline, approaching the structure of quartz rock. It is considered to be of Cambrian age (No. 15), and may be conveniently termed the Torridon sandstone, from mountains of this name in Applecross. Over it are two quartzites: c^1, with annelid burrows, as on annexed cut (Fig. 22), a greyish-white rock; the other, c^2, reddish brown with fucoid impressions,

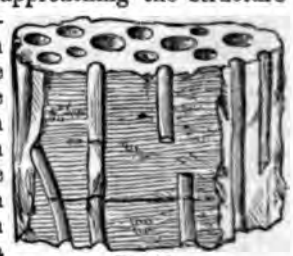


Fig. 22.

as on annexed cut (Fig. 23). Mountains capped by the former look as if snow-clad, and get the local name of "Greyheads." Over this is a limestone (*e*), in which at Durness, in N.W. Sutherland, fossils have been found, considered to be of lower Silurian age. The above succession is undoubted, being distinctly seen on many clear sections. To these beds there succeeds eastwards a great series of slaty rocks (*d*), "newer gneiss," mica and chlorite schists, flagstones, and clay-slates, which, though generally highly crystalline and without fossils, must, according to this view of the mineral succession, overlie the limestone and quartzites, and with them be in the place of the lower Silurian formation (No. 14). These crystalline schists, which also contain beds of limestone, occupy the central Highlands and the N.W. of Ireland as far as Galway bay. Mainly along an axial line, granite (*g*) breaks through the schists, and forms the highest mountains in the Connemara, Donegal, and Scottish Highlands; and owing partly to this cause, partly to a bending under pressure connected with their upheaval, the strata are thrown into immense folds in their line of dip, which is either N.W. or S.E., the strike being N.E. and S.W., producing synclinal troughs and anticlinal breaks, on one of which latter lies the great glen of Scotland.



Fig. 23.

Here (Fig. 24) c^1, c^1 are quartzite beds; c^2 of



Fig. 24.

Fig. 21 not yet identified; *d* the upper schists, with limestone beds; *g* granite, forming the shoulder of Ben Nevis; *t*, greenstone (hornblende and felspar), forming the axis and mass of the mountain.

The sections in Applecross and Assynt are truly magnificent. The sandstone mountains, with the quartzite cappings, rise to the height of 3500 and 4000 ft. from the wooded shores of the wild sea lochs, often as isolated as the Pyramids; thus shewing an amount of denudation without any parallel in the British isles. [See *Note* at the end.]

98. English and Irish Cambrian. — This lowest fossiliferous formation is divided into two groups (No. 15):—1. The lower or Longmynd, consisting of (*a*) the Llanberris and Anglesey slates and Harlech grits, in all 3000 ft. thick, with annelid burrows and 20 species of fossils, trilobites and other crustaceans, brachiopoda, &c.; in Wicklow and Wexford the singular Oldhamia coral (Fig. 25); and (*b*) the Menevian beds of St. David's Head and Dolgelly, with 40 species of fossils, of which one is the largest known trilobite, being 1 ft. 10 in. long. 2. The upper group has also two members: (*a*) the Lingula flags of Merioneth and St. David's Head, 5000 ft. thick, with 40 species of like fossils; and (*b*) the Tremadoc slates, which are very partial, 1000 ft. thick, and with 36 fossil species, half of which are allied to lower Silurian types. Here bellerophon, orthoceras, cyrtoceras, and other cephalopoda have their lowest horizon; *L. Davisii* (Fig. 26) is characteristic.

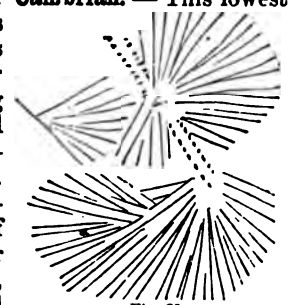


Fig. 25.
OLDHAMIA ANTIQUA.



Fig. 26.
LINGULA DAVISII.

99. The Silurian System.—This great formation (No. 13) is extremely distinct in its mineral character and fossil groups. It consists of hard, dark-coloured slates, flagstones and sandstones, limestones and fine roofing slate, with vast intercalated igneous products, some crystalline, others in the state of tuffs or ashes, in fact semifused or disintegrated lava re-arranged by water. Granite bosses (*g*) everywhere protrude, converting, in Dumfries and Down, coarse slates into a gneiss consisting of quartz, felspar, and mica. Three fossil groups have such preponderance as to be almost peculiar to the system: 1. The graptolites or "sea pens" (Fig. 27), family of polypi, number 57 species, range through

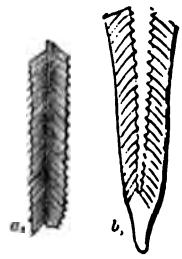


Fig. 27.
a, Diplograpsus pristis.
b, Didymograpsus Murchisoni.

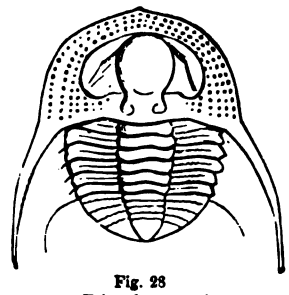


Fig. 28
Trinucleus ornatus.

the whole formation, and then disappear from the geologic record. 2. The trilobites (Fig. 28), extinct crustaceans of 3-lobed body, which underwent metamorphoses like crabs, and were discovered in 1870 to have had, when perfect, 8 legs. They number 263 species, of which a very few rise into the Old Red Sandstone. The family then becomes extinct. 3. The third group is that of the brachiopodous bivalve shells, the species of which are double the number of other bivalves; this ratio gradually diminishes upwards till, in the present creation, they are only one-forty-fourth of the whole number of bivalves, reckoning even the discoveries in the late dredgings in the Atlantic Ocean; the genus *Orthis* is characteristic (Fig. 29).



Fig. 29.
ORTHIS FLABELLUM.

The entire fossil fauna numbers about 1500 species; there are many corals, encrinites, and other

lower forms; some star-fishes, very like existing species, are perfectly preserved in "the mudstones!" Here, in the upper and lower Ludlow rock, the vertebrate type first appears; fishes of the genus Pteraspis have close relations with the sturgeon, high in the scale of fish organization.

The divisions of the system are as follows, order ascending: — 1. Lower Silurian: (*a*) Arenig or stiper-stone beds, 10,000 ft. thick; (*b*) Llandeilo flags, 4500 ft.; (*c*) Bala and Caradoc beds, 12,000 ft. 2. Upper Silurian: (*a*) Llandovery formation, consisting of Lower Llandovery rocks, 600 to 1000 ft.; (*b*) Upper Llandovery or Mayhill sandstone, 800 ft. thick, both forming beds of passage; (*c*) Wenlock formation, consisting of (1) Woodhope limestone and shale, and (2) Wenlock limestone and shale; total, 4000 ft.; (*d*) Ludlow formation, (1) Lower Ludlow beds, 1050 ft., and (2) Upper Ludlow, 780 ft. —Total thickness about 30,000 ft.

100. Old Red Sandstone and Devonian. — These two formations (No. 12) seem to have originated contemporaneously on different portions of the same horizon, the former as a fresh-water or estuary sediment, the latter as a marine deposit. This is inferred from the resemblance of the Old Red fishes to those of the American and African rivers; from the total absence of corals in the Old Red, and their abundance in the Devonian; the abundance of marine mollusca in this latter, and the occurrence as yet of but one shell in the Old Red, a fresh-water mussel, the *Anodonta Jukesii* (Fig. 30), from the Kiltorkan beds in the S. of Ireland. Both formations contain land plants allied to those of the coal. Each contains 3 groups: —1. The lower Old Red Sandstone consists of shales, slates, and "pavement" or flagstone, and conglomerate, lying along the S.E. of the Grampians, developed also on the shores of the Moray Frith, especially in Easter Ross. Fish of the genus Cephalaspis (Fig. 31), and the huge crustacean Pterygotus, 5 or 6 ft. long and 1 ft. broad, characterize the group, to which also belong some beds at the base of the Caithness series, containing grasslike plants and remains of Pteraspis. 2. The middle group comprises the bituminous and red schists of Caithness, Orkney, and the S. shores of the Moray Frith. This and the lower division are remarkable for the number and size of their fish remains of the Ganoid order, having shining scales, and allied to the bony pike; the largest being the Asterolepis, a cartilaginous fish with bony armour, and between 20 and 30 ft. long. A patch also occurs near Tarbet-ness. The fishes of this division number 70 species. 3. The upper division lies next to the coal in Fifeshire, and at Dura Den near Coupar is a yellow sandstone abounding in fish; patches occur at Dunnet Head, John O'Groat's, and Elgin, and the Old Red of the Tweed valley is probably of this age. The division has yielded 15 species of fish.

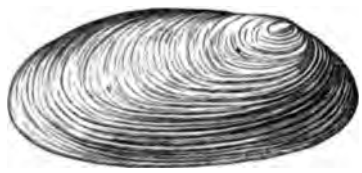


Fig. 30.

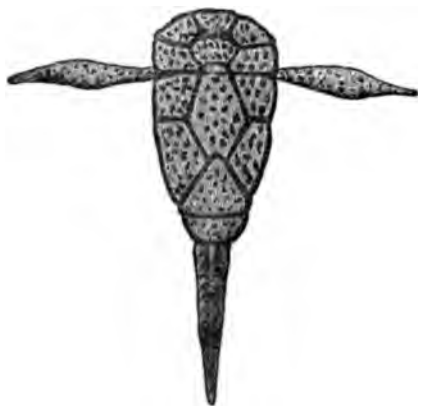


Fig. 31.
CEPHALASPIS LYELLII.

The Devonian of Devon and Cornwall also forms three groups:—1. The lower or Lynton group: (*a*) soft shales with corals and 18 species of bivalves; (*b*) sandstone without fossils. 2. The Ilfracombe group: (*a*) soft shales and Plymouth and Torbay limestone, 104 bivalves, 51 corals, &c., and fish remains the same as those of the Old Red Sandstone in England and Russia. 3. The Pilton group: (*a*) sandstone with land plants and marine shells; (*b*) slates and limestones with fossils; corals, trilobites, and mollusca 150 species, of which 30 pass up into the next system. Two bivalves only are common to this and the Silurian formation. Old Red rocks form entire counties in the United Kingdom, and rise into high mountains.

101. Carboniferous System.—The economic value of its coal, ironstone, freestone, and limestone, renders this formation the most important of the whole series. It consists of three parts: limestone at the base, millstone grit in the middle (No. 11), and the "coal measures" above, (No. 10). At the base of the limestone, there are shales full of fish remains; in the N. of England, sandstones and shales are interstratified with it; and in Yorkshire beds of sandstone, shale, limestone, and imperfect coal (Yoredale rocks of Phillips) lie between it and the millstone grit. This limestone is chiefly made up of corals and encrinites; many species of orthoceras and other cephalopods, 700 of marine shells, and 70 of fish have been found in it (Fig. 32); it no doubt originated in a coral sea of pure water like that of the Bahamas. The millstone grit is a coarse freestone, made up of the ingredients of granite, and contains coal plants: it caps the highest mountains of the Pennine chain, but is not known in Scotland or in Ireland (?). The coal measures (*c*, *c*, *c*), annexed cut (Fig. 33), consist of sandstone, shale, ironstone, and coal; and are usually found in basins or troughs, which are either original surfaces of deposition, or formed since by fractures. The bottom of the basin being usually Old Red Sandstone (*a*), rising up on either side and bound-



Fig. 32.
PECOPTERIS AQUILINA.

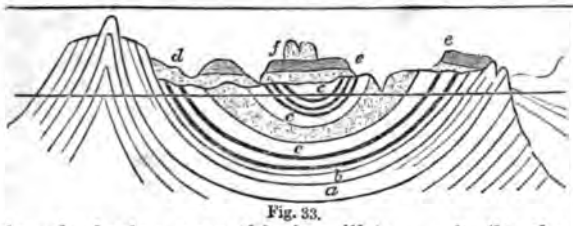


Fig. 33.

ing the basin; over this is millstone grit (*b*), the cover or lid being unconformable beds of the newer formations (*d*, *e*, *f*), New Red Sandstone, Lias, Oolite, &c. The fossils are chiefly land plants, but there are also fresh-water, estuary, and marine shells, with remains of batrachian reptiles (allied to the frogs), gigantic white ants, crickets, cockroaches, and curculionidæ, besides many fishes, of which the *Holoptychius Hibberti* traverses the whole formation from the upper coal measures to the lowest limestone. The plants are a few coniferous trees allied to the Norfolk Island pine (*Araucaria*), a few species allied to the Arums, ferns and tree-ferns, lycopodiums (*Lepidodendron*) (Fig. 34), and equisetums (*Calamites*) (Fig. 35). In the pure coal


Fig. 34.
LEPIDODENDRON ELEGANS.

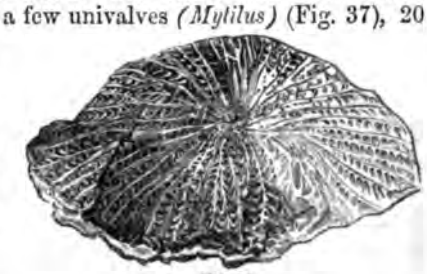

Fig. 35.
CALAMITES CANNÆFORMIS.

itself remains of all these have been detected, shewing how coal was formed. The beds of ironstone seem to have originated in the segregation of the iron mechanically diffused in the sediment, and from decaying vegetable matter, in the same way as our "meadow" ore is formed; the iron would be in the state of oxide, and the abounding carbonic acid (in such a state of things) would convert this into a carbonate, with which clay would be mixed, or vegetable matter, forming the clay carbonate and the "blackband." Sir Charles Lyell accounts for the purity of the coal amid such a mass of sediment by what he saw in the Mississippi delta; a dense margin of reeds and grass prevents any sediment from entering the lagoons where vegetable matter is accumulating. In this vast delta layers of sediment alternate with one another, as we find in our "measures," and cover and underlie pure vegetable beds. While this mechanical process is at work, animal and chemical forces are forming coralline limestones with shell and fish remains in the sea of Florida and the Bahamas. In such an archipelago enclosed on all sides by islands of the older rocks (Art. 48), was formed the limestone of the central plain of Ireland, by far the largest body of this rock in the British isles, and in Europe out of Russia. The sedimentary beds have little development, however, and the coals and ironstones are in limited quantity. The vegetation and animal remains of the whole British series shew that the climate of the coal period was warm and moist, and nearly represented by that of New Zealand at the present day, where the fern tribe have their greatest development, and the coniferæ are in greatest numbers. In England the crystalline and sedimentary beds are both greatly developed, being respectively 4000 and 18,700 ft. in thickness; in Scotland the sedimentary beds vastly predominate. The limestone does not form a thick fundamental rock; it is, in fact, intercalated among the coal measures in all positions from base to summit, the total thickness in Lanark and Fife being about 150 ft., and in Ayr 200 ft. The Scottish series is thus lower than the English, yet such is the unity of this great system, that the fossil groups are the same. The following are the numbers of the fossil species in these beds in the W. of Scotland, determined up to the present time (Aug. 1871). The total number of species is about 170; of these 60 are corals, 71 crustacea, 127 lamellibranchiate mollusca, and 50 brachiopodous; 75 gasteropoda, 43 cephalopoda; 90 plants, 84 fishes, and 7 reptiles. The orthoceras (Fig. 36), a straight chambered cephalopod, is widely distributed. [*Mr. Armstrong in Transac. Geo. Society of Glasgow*, Vol. III., *Aug. 1871.*]


Fig. 36.
ORTHOCERAS LATERALE.

102. Permian System.—This system rests unconformably over the coal, and is the highest group in the palæozoic series. It is so placed because out of 150 species of fossils, not one passes into the next group above, while a few descend into the carboniferous system. There are, however, at St. Cassian and Hallstadt in the Austrian Alps beds of passage connecting the palæozoic and mesozoic series. The English Permian has three divisions:—1. The Lower,—angular conglomerates (*Roth-todt-liegendes*) and red sandstone, sometimes with marl and gypsum, in the Vale of Eden and county of Dumfries, with reptile tracks on Corncockle Muir; 2. Middle,—magnesian limestone (*Zechstein*) and marl slate (*Kupfer-Schiefer*), Nottingham to Tynemouth, 600 ft. thick; N.W. coast, 10 to 30 ft. 3. Upper,—sandstone of N.W. coast, 600 ft. thick; total thickness on N.W., 3630 ft., in N.E., 950 ft. There are two patches of No. 1 near Ayr; one at Holywood on Belfast bay of No. 2, and another near Ardtreagh, in Tyrone, of No. 2. The entire fauna consists of 77 bivalves, a few univalves (*Mytilus*) (Fig. 37), 20


Fig. 37.
MYTILUS SQUAMOSUS.


Fig. 38.
SYNOCLADIA VIRGULACEA.

species of fish, a lacertian reptile *(Proterosaurus)*, and several batrachian, with many encrinites, corals, &c., as *Synocladia* (Fig. 38).

The fishes of the Permian and older formations are distinguished by a peculiar structure of the tail; the tail-fin was unequally lobed, like that of the sturgeon and shark, and, as in these, the vertebral column extended into the upper and larger lobe; fishes of the later formations, and, with a very few exceptions, of the existing creation also, have the tail-fin equally lobed, like that of the salmon, and herring, and the vertebral column not prolonged into either lobe, but stopping short near the point of bifurcation.

103. The Trias or New Red Sandstone. — Of the three groups whence this formation has its foreign name, only two exist in the British Isles, the middle division, the Muschelkalk, being absent. The British divisions are: (1) Lower New Red or Bunter Sandstone, about 1500 ft. thick; and (2) the Upper New Red Sandstone or Keuper, with rock-salt, and clays containing gypsum. The two form the great central plain of England, encircling the Pennine chain, and extending with breaks into Devon. The Keuper is fully developed on the S.E. and E. coast of Antrim, where it contains rock-salt. In Scotland the Trias is as yet recognized in but one spot near Elgin, where the lower beds (No. 1.) contain remains of a small reptile, Hyperodapedon, of most peculiar structure, unlike any other fossil reptile, but most closely allied to a living reptile, the Sphenodon, found only in New Zealand; a remarkable example of the persistency of organic forms. Of other fossil species there is one marsupial, several other reptiles, as the Cheirotherium of the Storeton quarries near Birkenhead, and Dinosaurians of the dolomitic conglomerate of Bristol, which is of lower Triassic age; encrinites abound (Fig. 39).



Fig. 39.
ENCRINITES MONILIFORMIS.

104. The Jurassic Formations.—These consist of two great divisions, the Lias and Oolites.

I. LIAS.—The RHÆTIC BEDS resting on the Upper Trias are true beds of passage into the Lower Lias. They are chiefly cream-coloured impure limestone, distinguished so universally by one shell as to be called the *Avicula Contorta* bed of the Lias. The thickness does not pass 50 ft., and is usually much less.

The Lias formation consists of dark stiff clays, finely laminated shaly clays, limestone, often a coarsely crystalline marble, in irregular beds, and white or cream-coloured fine grained impure limestone, used for lithography. But these do not occupy determinate places. (1) The Lower Lias, reaching 900 ft. of thickness, is divisible into 7 zones, each of which is characterized by peculiar species of ammonites which do not pass into the other zones, though from a half to a fifth of the other fossils do so pass. (2) The Middle Lias or marlstone consists of three distinct zones; and (3) the Upper Lias of two, the highest being sandy beds passing into the Lower Oolite. The beds are conformable from top to bottom, and constant in their positions across England from Lyme Regis to Whitby. The formation is most prolific in fossils; there are 117 species of fish, several plants and insects, nearly 1000 mollusca, of which more than one-fourth are ammonites. But the most remarkable fossils are several species of two genera of huge marine air-breathing reptiles, Ichthyosaurus (Fig. 40), some of which measured 24 ft., and Plesiosaurus (Fig. 41), some of 18 to 20 ft. They are of extraordinary structure, and their habits, thence deduced, most singular. Skye has the lower and middle beds; the N. of Ireland the Lower Lias and the Rhætic beds.



Fig. 40.
ICHTHYOSAURUS COMMUNIS.



Fig. 41.
PLESIOSAURUS DELICHODEIRUS.

II. OOLITES.—The Oolites or Jurassic proper are a series of clays and sands, arenaceous limestones or calcareous sandstones, of enormous thickness, and occupy a zone across England 30 miles broad. The principal beds are shewn in the annexed cut

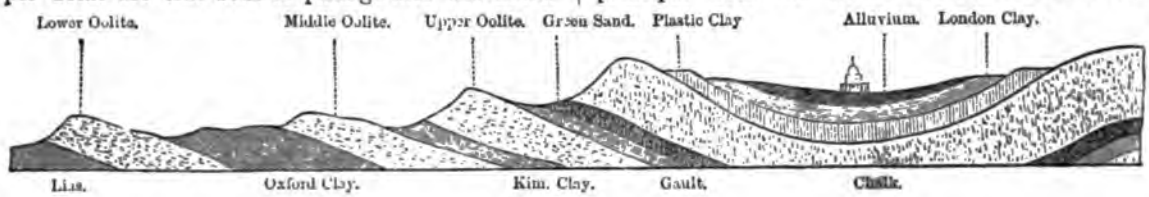


Fig. 42.

(Fig. 42). In passing from London to Gloucester or Birmingham the beds rise from below one another in succession, the escarpments directed N.W., the clays being worn away and the limestones standing out. The clays are chiefly in pasture, the limestones under culture. The fossils are extremely numerous, all forms of life being represented. The Purbeck beds at the top, chiefly fresh-water, and a very local

formation, are wonderfully prolific in every order. The Oolites are represented in Scotland by the lower and middle beds, on the E. coast of Skye and at Brora in Sutherland, at which latter they contain coal beds 3½ ft. thick; but they do not occur in Ireland; the chalk series there rests upon the Lias. The following is a complete list of the beds, of which some are left out in the section, order ascending:—1. Inferior; 2. Fuller's earth, very local (Bath); 3. Stonesfield slate; 4. Great or Bath Oolite; 5. Forest marble; 6. Cornbrash; 7. Kelloway rock; 8. Oxford clay; 9. Coral rag; 10. Kimmeridge clay; 11. Portland sands; 12. Portland stone; 13. Purbecks (local), fresh-water. No fossil species, vertebrate or invertebrate, is common to the Oolites and the overlying chalk series.

105. Cretaceous Series.—The principal member of this series is the white chalk, a pure limestone; and there are also impure limestones and some clay beds. The position of these is shewn in the last cut (Fig. 42). We have first, in an ascending order, the Wealden beds, sands, clays, and limestone, a series chiefly fresh-water, embraced in the lower cretaceous or Neocomian formation, and occurring chiefly in the Weald of Kent and Surrey, where they appear on account of extensive denudation between the N. and S. Downs. They were formed in the delta of a great river, and have yielded some enormous reptiles. The Speeton clay at Flamboro' Head is on the same horizon. The upper cretaceous series consists of the Gault, a dark blue marl 100 ft. thick, and very fossiliferous; over it are the chloritic greensands; next chalk marl; and over this the lower white chalk, several hundred feet thick without flints; and the upper white chalk with flints. The entire series, more especially this upper member, is most prolific in the remains of life; and it is not a little remarkable that many of these survive to the present day, and have been very recently found existing at great depths in the Atlantic, though before supposed to be long extinct. On the floor of that ocean also, there is now being thrown down, mainly through animal influence, a deposit very much resembling the ancient chalk.—This series has no representative in Scotland, except a few flints with chalk fossils over the granite clays of Aberdeen; their origin is wholly unknown. In the N. of Ireland the series is represented by three distinct beds of greensand, the lower resting on Lias, and by white, hard chalk with flints. Of the white chalk and greensand the fossil forms are most varied: sponges, echini, nauliti, belemnites (Figs. 43, 44, 45), ammonites, baculites, terebratula, pecten, oysters, but very few univalves; many reptiles, fishes, chiefly sharks, turtles, but few traces of plants.



Fig. 43
AMMONITES MONILIS.

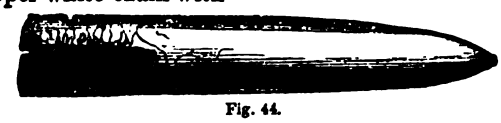


Fig. 44.
BELEMNITES MUCRONATUS.



Fig. 45.
BACULITES FAUJASII.

106. Tertiary Formations — Eocene.—We enter now upon a vast group of strata which contain in abundance the remains of our existing life-forms. At the base of these formations, and succeeding the chalk, is the Eocene group, which exhibits to us the dawn of the existing order of things (see Fig. 42). The group has less than 10 per cent. of existing species of shells, for it is from the number of these that the groups are arranged. There are three divisions, Lower, Middle, and Upper:—1. The lower has three groups, represented by (*a*) the sands of Thanet; (*b*) the clays and sands of Woolwich and Reading, both divisions formerly named the plastic clay; and (*c*) the London clay. 2. The middle series is developed on the S. coast: (*a*) the lower or Alum bay and Bournemouth beds; (*b*) the Brackleham bed, near Chichester, which out of 393 shells has 240 peculiar to it. 3. The upper group has four divisions: (*a*) the Barton (Hants) beds, (*b*) those of Headon, (*c*) those of Osborne, and (*d*) those of Bunbridge, all three in the Isle of Wight. The fossils are too numerous and varied to specify. The great nummulitic formation of the mountain chains of Europe, Asia, and Africa, belongs to the middle and upper Eocene group.

107. The **Miocene** tertiary series has about half its testaceous remains now existing. It is a vast formation out of England, but here is represented only by the Hampstead beds in the Isle of Wight, 170 ft. thick, but occupying a very small area, and by the lignite beds and clays of Bovey Tracey in Devonshire. Both belong to the lower Miocene. From certain leaf beds in volcanic ash, the trap or basaltic formation of Mull and the N.E. of Ireland are considered to be of this age.

108. The **Pliocene** tertiary strata have but a small proportion of the shells of extinct species. In England there are two groups, the White or Coralline crag of Suffolk, overlying the London clay (the Miocene being wanting), and the Red crag of the same county, both being very limited in extent, but abounding in fossils, among which are remains of the mastodon, whale, rhinoceros, and also of an ancient horse, Hipparion.—Above these Sir Charles Lyell places the Norwich crag, a bed of passage into overlying glacial beds at Chillesford in Suffolk, the submerged Cromer forest bed with clays, lignite, and numerous quadrupeds; certain drifts on the Norfolk cliffs, glacial beds in the county of Wexford; and, younger than these, the Bridlington glacial drifts near the mouth of the Humber.

109. Post-Pliocene Formations.—This term includes all the upper formations not now in progress; they are chiefly deposits of clay and sand containing shells, which indicate a colder climate than that which now prevails. In harmony with this in-

dication, are striations on the rocks below and on the loose local, or travelled stones (boulders), included in the deposits, similar to those which are produced at the present time under the action of moving ice in glaciers and icebergs. They occur everywhere in Scotland and Ireland, and in the N. and central parts of England. In either hemisphere (N. and S.) they scarcely occur inside the 50th parallel in the Old World, and the 40th in the New.

110. The Recent Formations are all such as are now in progress, and contain no remains but the existing forms of animal and vegetable life.

111. The Igneous Rocks.—The products of fire are of two kinds: those formed beneath the crust under pressure, such as granite and porphyry, and those ejected in successive sheets, in the manner of lava perfectly or partially fused, either subaërially or on a sea bottom of moderate depth, and which are termed ancient volcanic or trap rocks, from the terraced outline of the hill-sides formed of them (Swedish *trappa*, a stair). Such is the great series of basaltic rocks overlying the chalk in Antrim and Londonderry, forming the greater part of Mull, Skye, and other lesser islands, and the middle and upper portions of the great Old Red ranges which bound the Scottish coalfields from sea to sea. In beds of volcanic ash in this series, the writer of these pages discovered in 1842 leaf beds of Miocene plants; the Duke of Argyll made a similar discovery in 1850, quite independently, it being impossible that his Grace could have had any knowledge of the previous discovery. The Antrim, Mull, and Skye traps are thus certainly of Miocene age. In regard to the age of those of central Scotland, it is only certain that they are newer than the coal; erupted through Old Red Sandstone they pass across the frontier line, and overlie sandstones of the carboniferous series.

Note referred to in Art. 97.—The idea of such a mineral succession in the W. Highlands, as that described in the text, was first suggested by Dr. M'Culloch in 1820. Sir R. Murchison began to advocate it in 1856, in consequence of the discovery of certain fossils by Mr. Peach; and did not cease till he considered he had obtained such evidence of its truth as to justify so sweeping a change as to place the whole of the crystalline schists of the central Highlands in the position of the lower Silurian rocks.—The view is strongly opposed by at least one very able physical geologist.

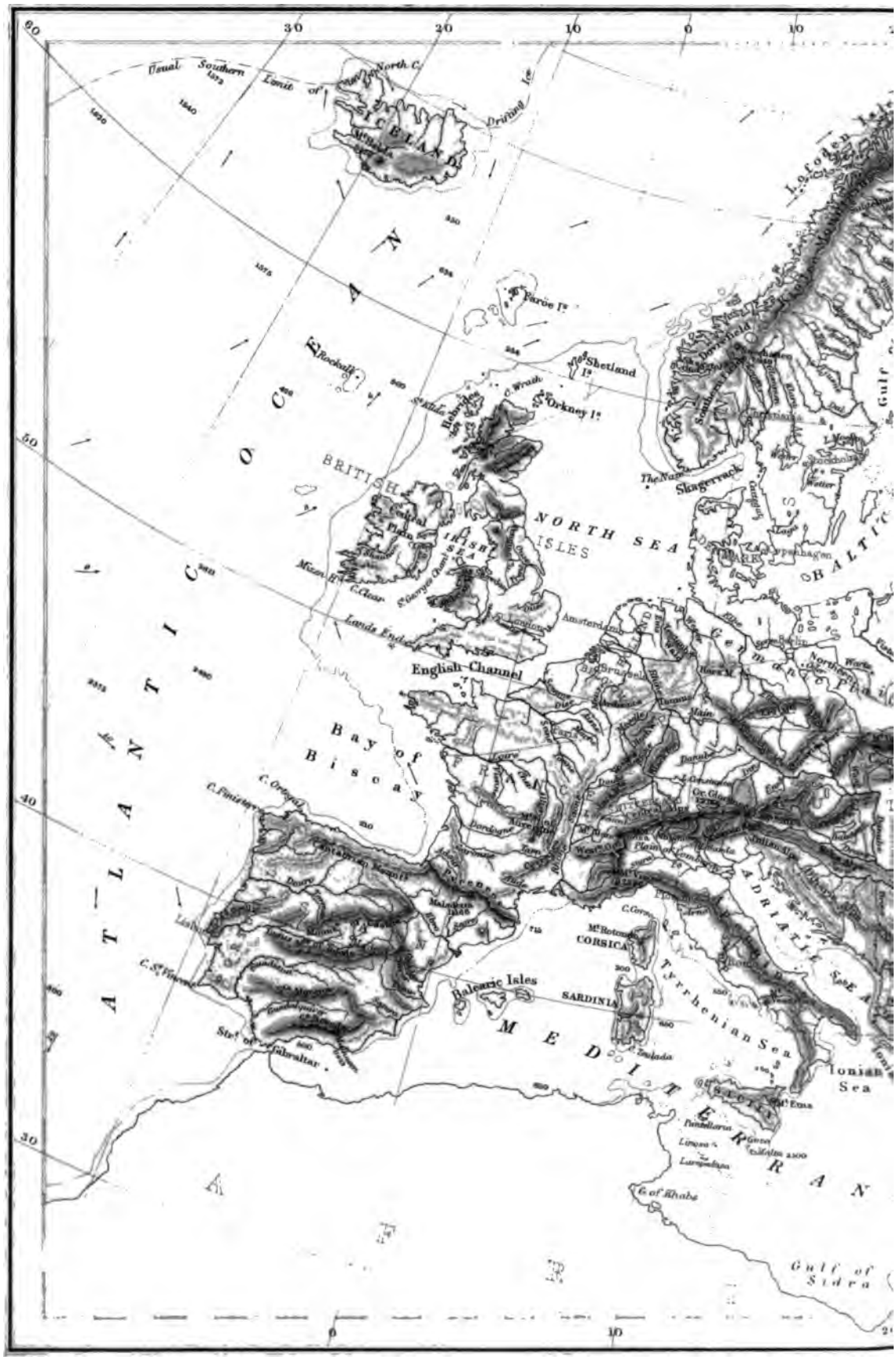
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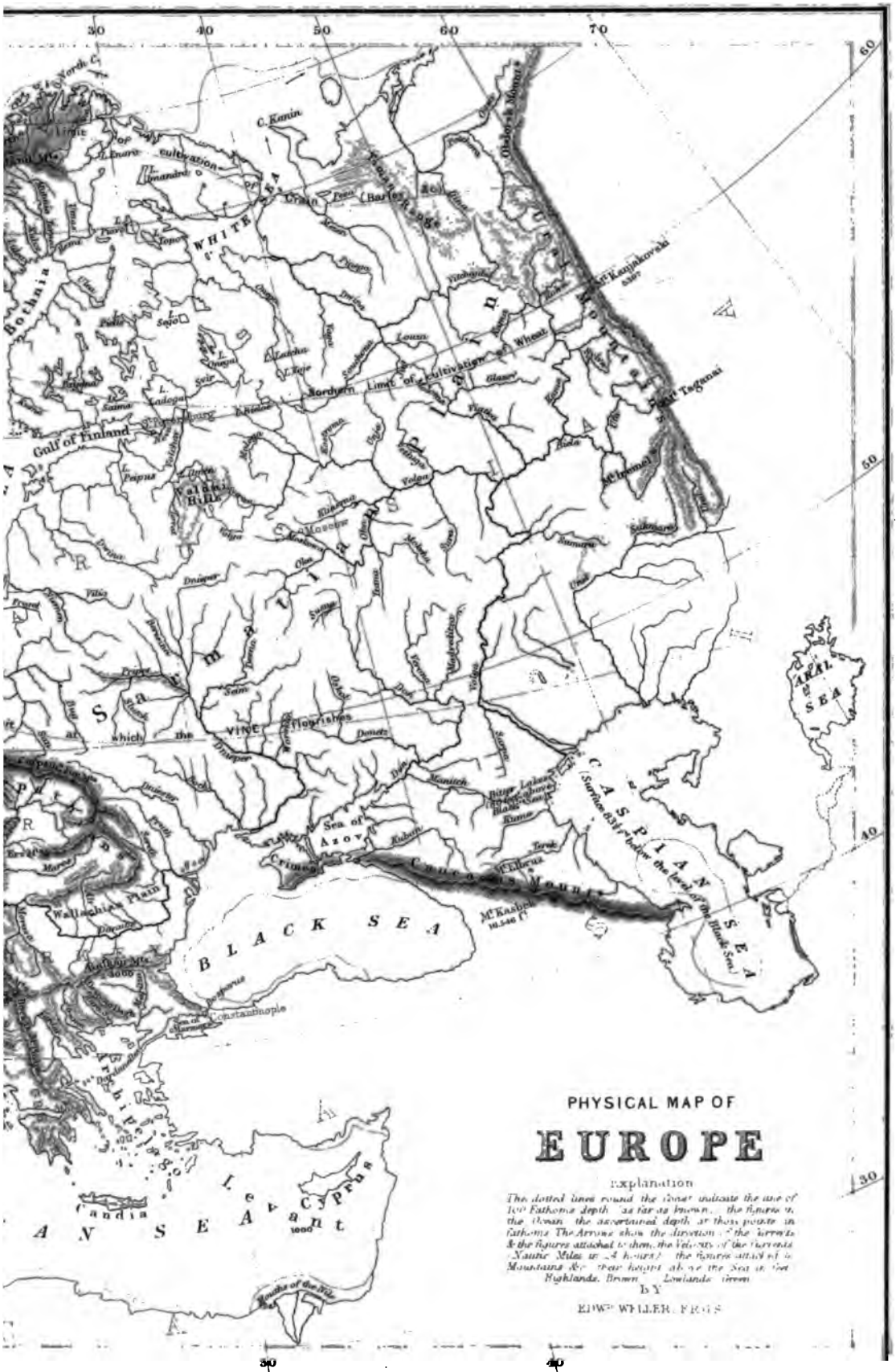


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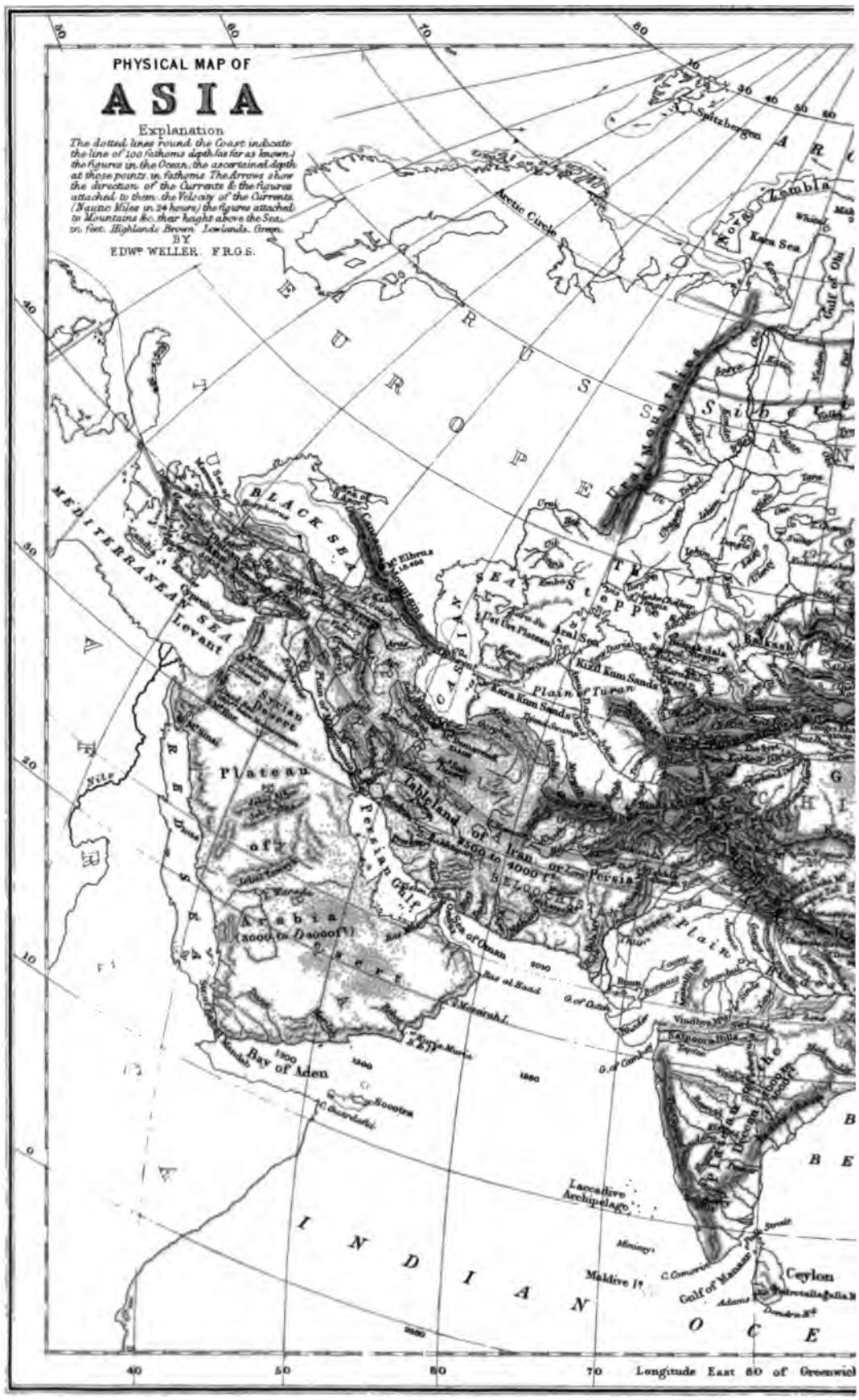

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ASIATIC
ORLD
EASTERN HEMISPHERE
North Pole
South Pole
Equator
ARCTIC OCEAN
ATLANTIC OCEAN
INDIAN OCEAN
PACIFIC OCEAN
ANTARCTIC OCEAN
SOUTH
RUSSIAN EMPIRE
CHINESE EMPIRE
TURKESTAN
PERSIA
INDIA
Calcutta
Bombay
Madras
Arabian Sea
Bay of Bengal
Ceylon
Tibet
Mongolia
CHINA
JAPAN
Nipon
ISLANDS
Sea of Japan
Philippine Islands
EAST INDIA ISLANDS
Sahara or Great Desert
Abyssinia
Somauli
Arabia
AUSTRALIA
Tasmania
Wilkes Land
Cape of Good Hope
Cape Horn
Cape Verd
Madagascar
Mauritius
Bourbon
St Helena
Ascension
Sandwich Land
Kerguelen I.
Amsterdam I.
St Paul I.
Crozet Is
Marion Is
Prince Edwards
Bouvet I
Enderby Ld
King Ld
Adelaide Ld
Graham Ld
Victoria Ld
Wilkes Land
Antarctic Circle
Trop. of Capricorn
Trop. of Cancer
Arctic Circle
Spitzbergen
Iceland
Greenland
Nova Zembla
Baffins Bay
Hudsons Bay
Behring Str.
Sea of Okhotsk
Kamtschatka
Aleutian Is
Sea of Kamtschatka
Lake Baikal
Aral Sea
Caspian Sea
Black Sea
Mediterranean Sea
Red Sea
Persian Gulf
Gulf of Guinea
Gulf of Siam
Gulf of Bengal
Gulf of Martaban
Gulf of Tonquin
Gulf of Siam
Java
Sumatra
Borneo
Celebes
Philippines
Moluccas
Solomon Is
New Guinea
New Zealand
Tasmania
Timor
Ceram
Banda Is
Admiralty Is
Caroline Is
Marianne or Ladrone Is
Sandwich Is
Marquesas Is
Society Is
Friendly Is
Navigators Is
Low Archipelago
Pelew Is
Loo Choo Is
Formosa
Hainan
Pescadores
Liquea Is
Bonin Is
Kurile Is
Aleutian Is
Behring Str.
Sea of Okhotsk
Sea of Japan
Yellow Sea
Gulf of Pekin
Gulf of Siam
Gulf of Martaban
Gulf of Tonquin
Gulf of Bengal
Gulf of Guinea
Gulf of Aden
Gulf of Persia
Gulf of Mexico
Gulf of Florida
Gulf of St Lawrence
Gulf of Mexico
Gulf of Florida
Gulf of St Lawrence
Hudsons Bay
Baffins Bay
Greenland
Iceland
Spitzbergen
Nova Zembla
Lake Baikal
Aral Sea
Caspian Sea
Black Sea
Mediterranean Sea
Red Sea
Persian Gulf
Gulf of Guinea
Gulf of Siam
Gulf of Bengal
Gulf of Martaban
Gulf of Tonquin
Gulf of Siam
Java
Sumatra
Borneo
Celebes
Philippines
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Solomon Is
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Friendly Is
Navigators Is
Low Archipelago
Pelew Is
Loo Choo Is
Formosa
Hainan
Pescadores
Liquea Is
Bonin Is
Kurile Is
Aleutian Is
Behring Str.
Sea of Okhotsk
Sea of Japan
Yellow Sea
Gulf of Pekin
Gulf of Siam
Gulf of Martaban
Gulf of Tonquin
Gulf of Bengal
Gulf of Guinea
Gulf of Aden
Gulf of Persia


ATLANTIC OCEAN
NORTH SEA
BRITISH ISLES
IRISH SEA
English Channel
Bay of Biscay
MEDITERRANEAN
Tyrrhenian Sea
Ionian Sea
Adriatic Sea
Gulf of Sidra
Balearic Isles
SARDINIA
CORSICA
Sicily
Mt Etna
Strait of Gibraltar
Faroe Is
Shetland Is
Orkney Is
Iceland
Usual Southern Limit of Drift Ice
Lands End
Amsterdam
Skagerrack
Gulf of Rhodes



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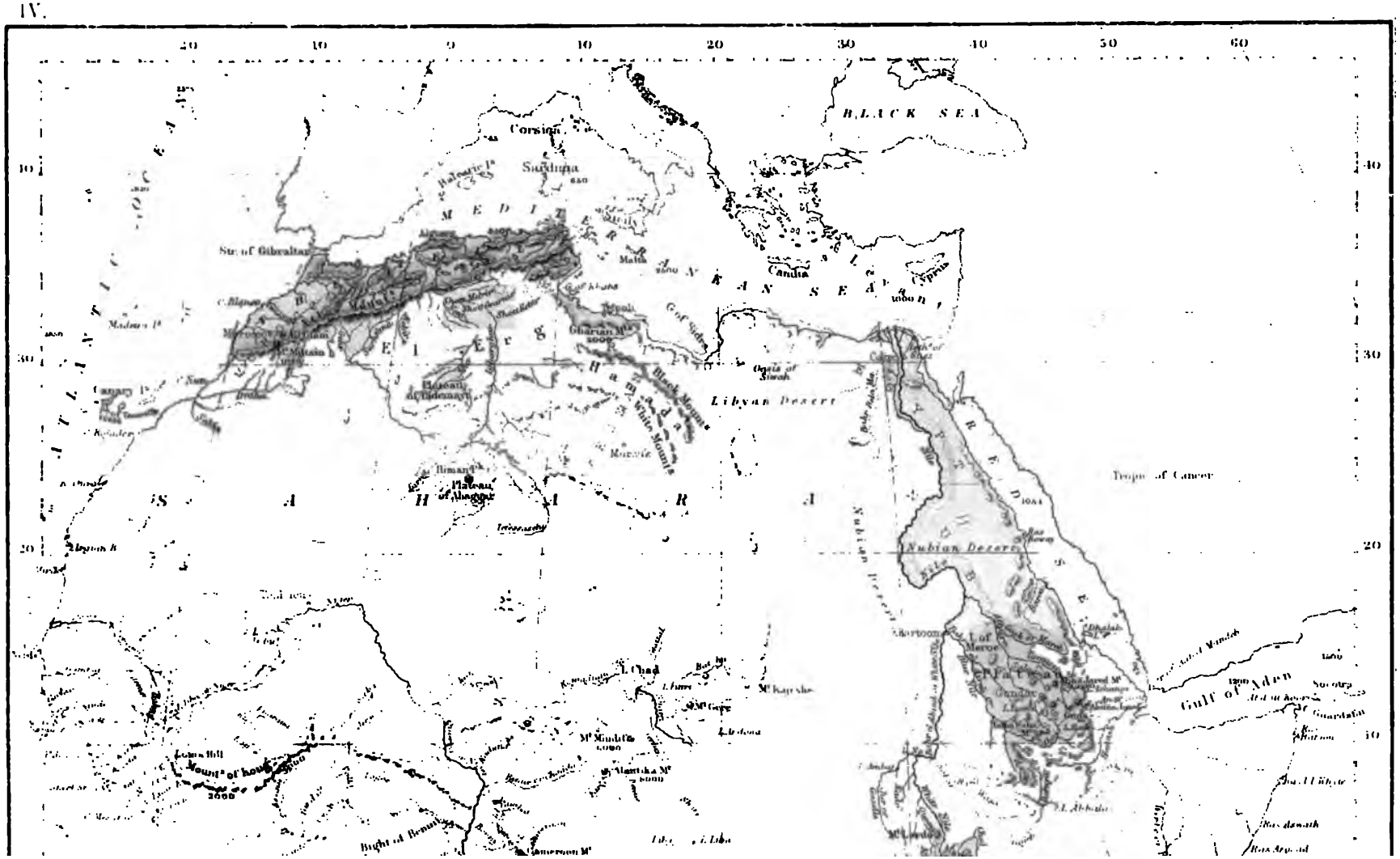
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PHYSICAL MAP OF
ASIA
Explanation
The dotted lines round the Coast indicate the line of 100 fathoms depth as far as known.) the figures in the Ocean, the ascertained depth at those points in fathoms. The Arrows show the direction of the Currents & the figures attached to them the Velocity of the Currents. (Nautic Miles in 24 hours) the figures attached to Mountains &c. their height above the Sea in feet. Highlands Brown. Lowlands. Green.
BY
EDWD WELLER. F.R.G.S.
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RUSSIA
ASIA
ARCTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
MEDITERRANEAN SEA
BLACK SEA
Caspian Sea
Aral Sea
Red Sea
Persian Gulf
Bay of Aden
Arabian Sea
Bay of Bengal
Arctic Circle
Spitzbergen
Nova Zembla
Kara Sea
Gulf of Ob
Siberia
Ural Mountains
Steppe
Plain of Turan
Kizil Kum Sands
Kara Kum Sands
Balkash
Plateau
Tableland of Iran or Persia
Desert
Arabia
Syrian Desert
Levant
Nile
Mt Elbrus
Mt Sinai
Sea of Oman
Deccan Plain
Laccadive Archipelago
Maldive Is
Ceylon
Gulf of Manaar
Longitude East 80 of Greenwich



C. Londons Glasgow.

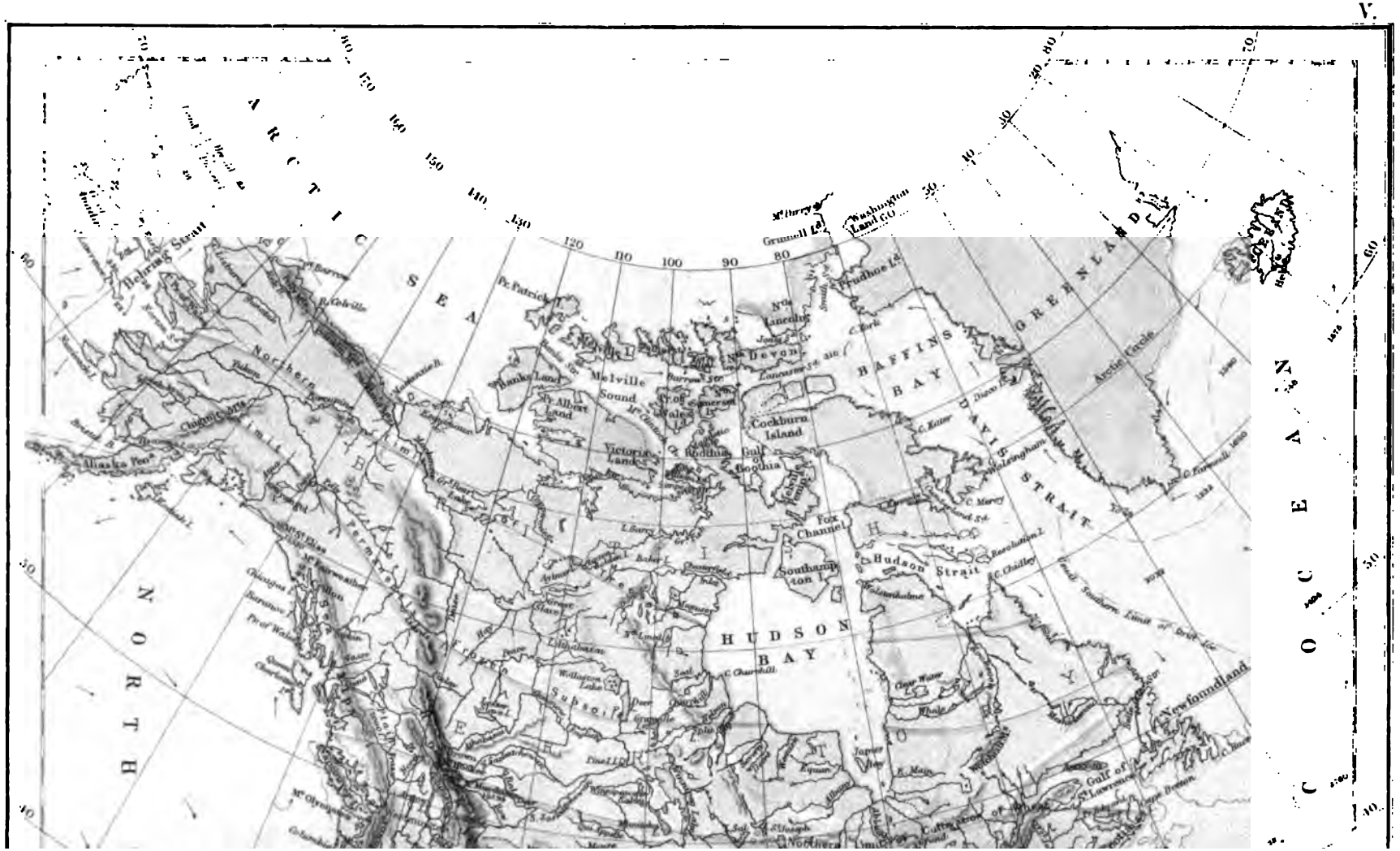
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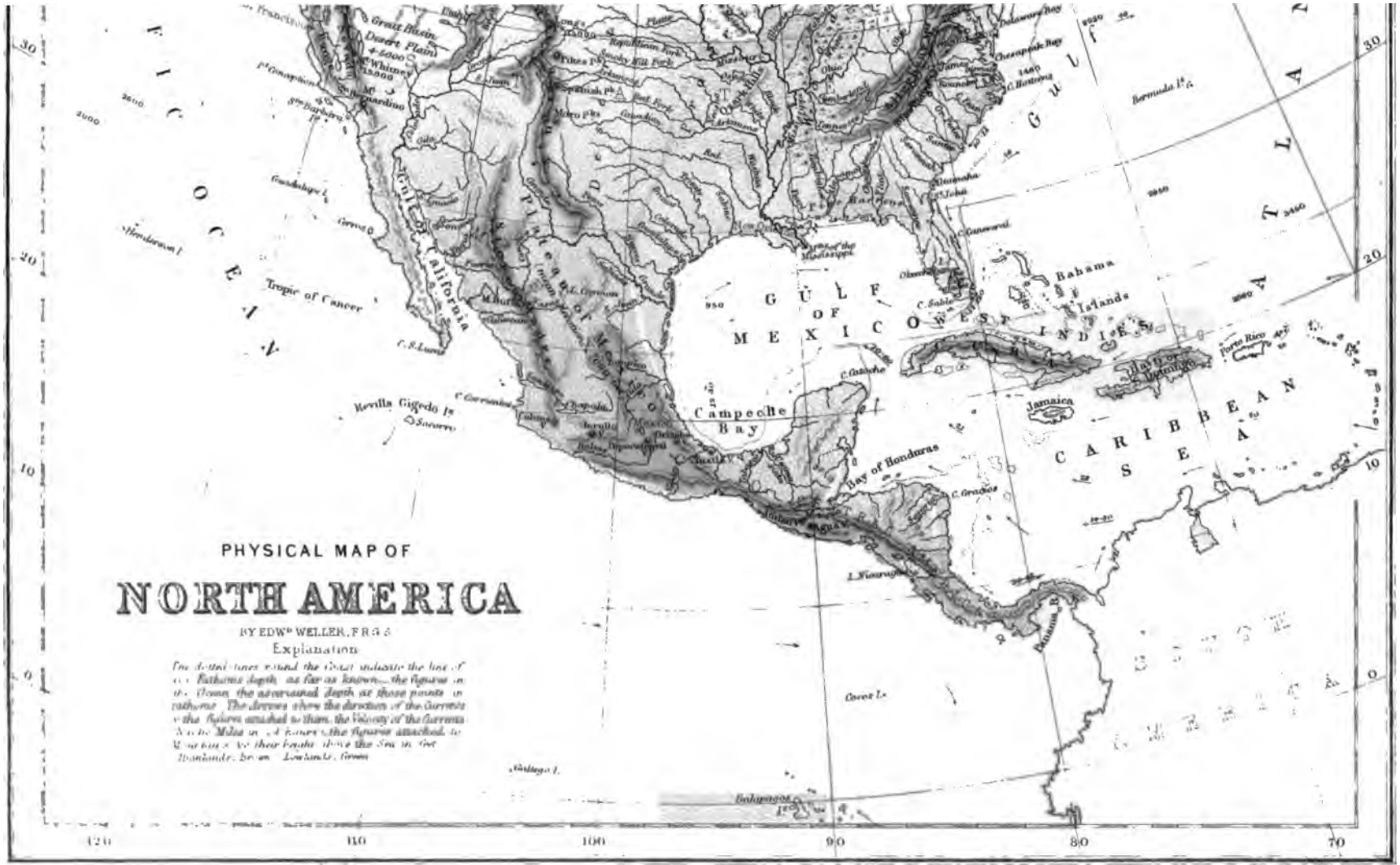

BLACK SEA
Corsica
Sardinia
MEDITERRANEAN SEA
Candia
Cyprus
Libyan Desert
Nubian Desert
Tropic of Cancer
Gulf of Aden
Mount of Mountains
Mt Gharian
Mt Mandara
Mt Alantika
Mt Kagesha
L. Chad
Khartoum
Cape Guardafui



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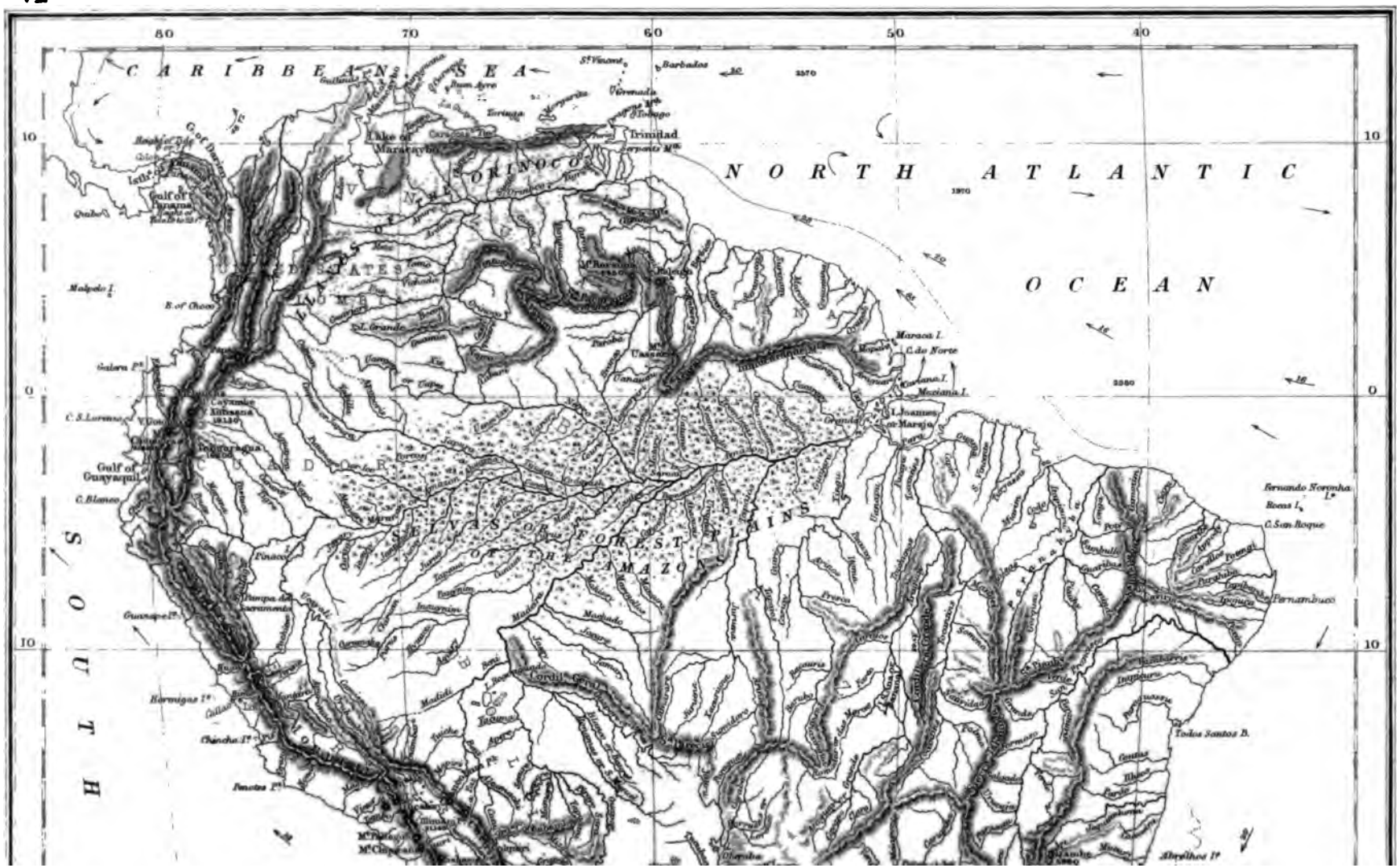
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ARCTIC SEA
NORTH PACIFIC OCEAN
HUDSON BAY
BAFFINS BAY
DAVIS STRAIT
GREENLAND
Behring Strait
Northern Limit of Trees
Melville Sound
Victoria Land
Cockburn Island
Fox Channel
Southampton I.
Hudson Strait
Newfoundland
Gulf of St Lawrence
Arctic Circle
Washington Land
Grinnell Land
Prudhoe Land
Devon
Lincoln
Wales
Baffins Land
Alaska
Yukon
Mackenzie R.
Great Slave Lake
Great Bear Lake
Athabasca L.
Winnipeg L.
Lake Superior
Labrador
Cape Farewell
Davis Strait
Hudson Strait
Cape Walsingham
Cape Chidley
Cape Charles
Cape Mercy
Cape Ellesmere
Cape Parry
Cape Bathurst
Cape Barrow
Cape Prince of Wales
Point Barrow
Mount St Elias
Mount Brown
Mount Hooker
Mount Olympus
Mount Hecla
Mount Parry
Mount Back
Mount Dease
Mount Sir James Ross
Mount Sir John Franklin
Mount Sir Edward Parry
Mount Sir John Ross
Mount Sir Edward Belcher
Mount Sir Leopold M'Clintock
Mount Sir Richard Collinson
Mount Sir Alexander Mackenzie
Mount Sir George Back
Mount Sir John Richardson
Mount Sir James Clark Ross
Mount Sir John Barrow
Mount Sir John Franklin
Mount Sir Edward Parry
Mount Sir John Ross
Mount Sir Edward Belcher
Mount Sir Leopold M'Clintock
Mount Sir Richard Collinson
Mount Sir Alexander Mackenzie
Mount Sir George Back
Mount Sir John Richardson
Mount Sir James Clark Ross
Mount Sir John Barrow



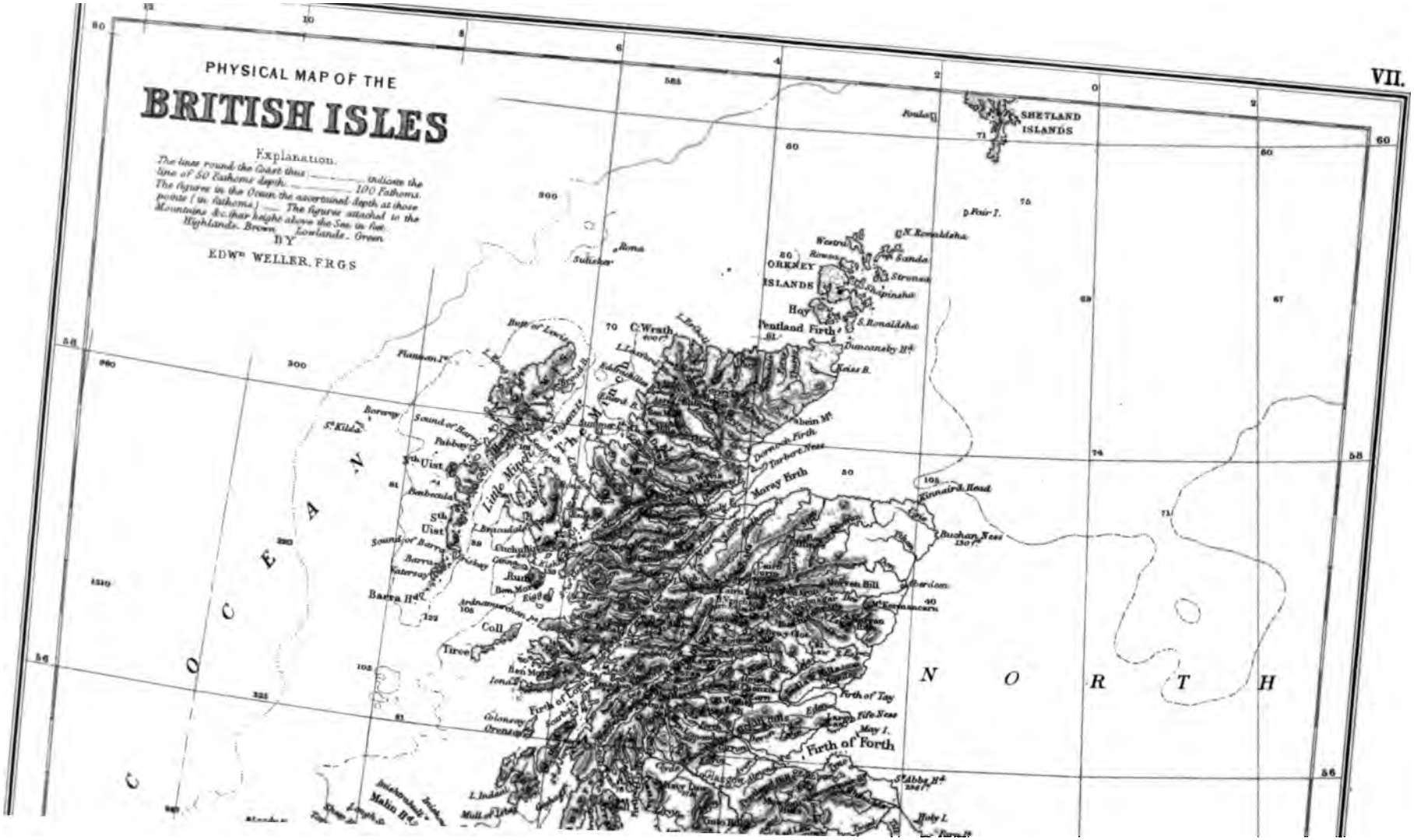
Edwd Weller Hall Lane Syn. London

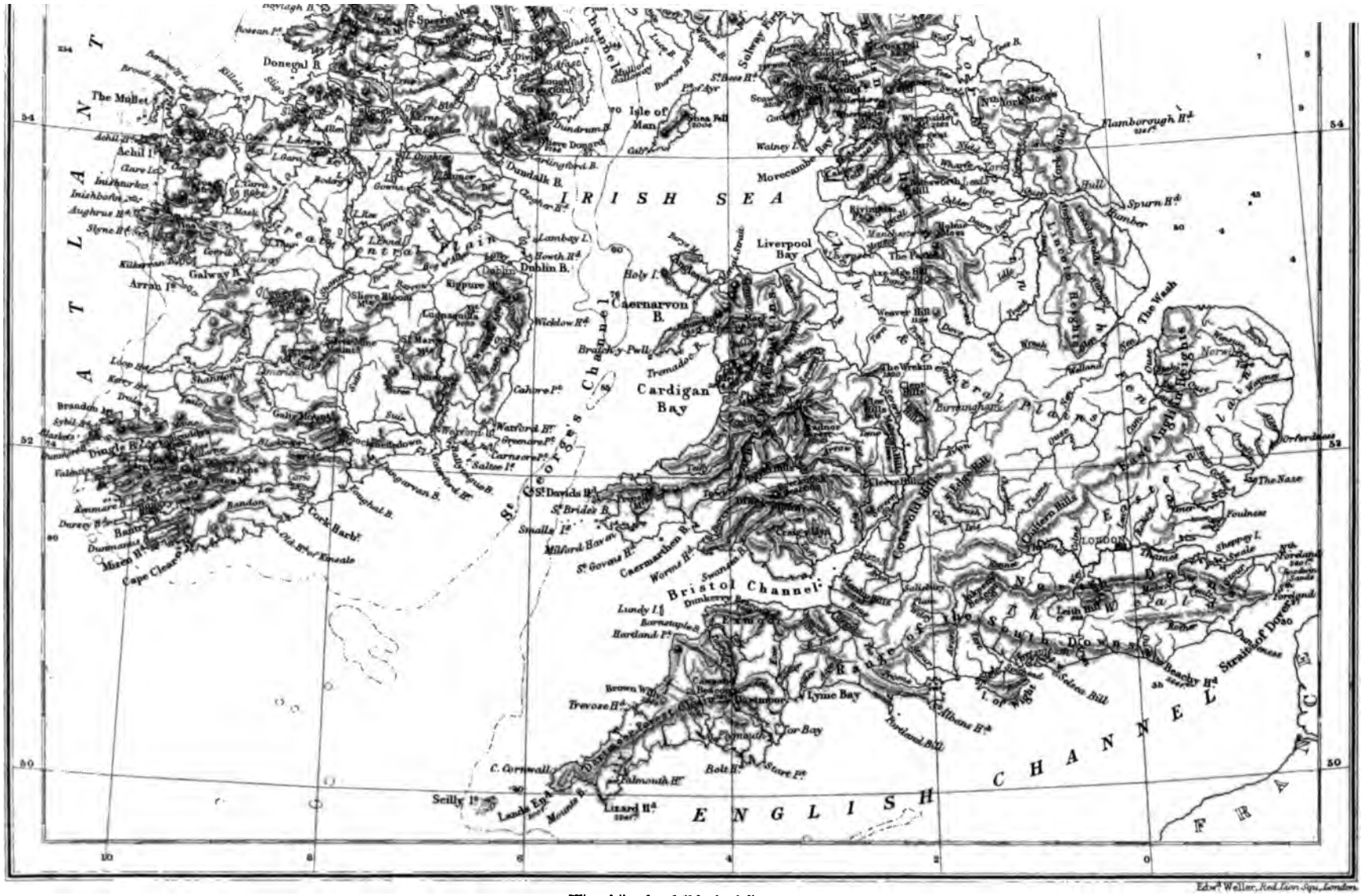
VI.

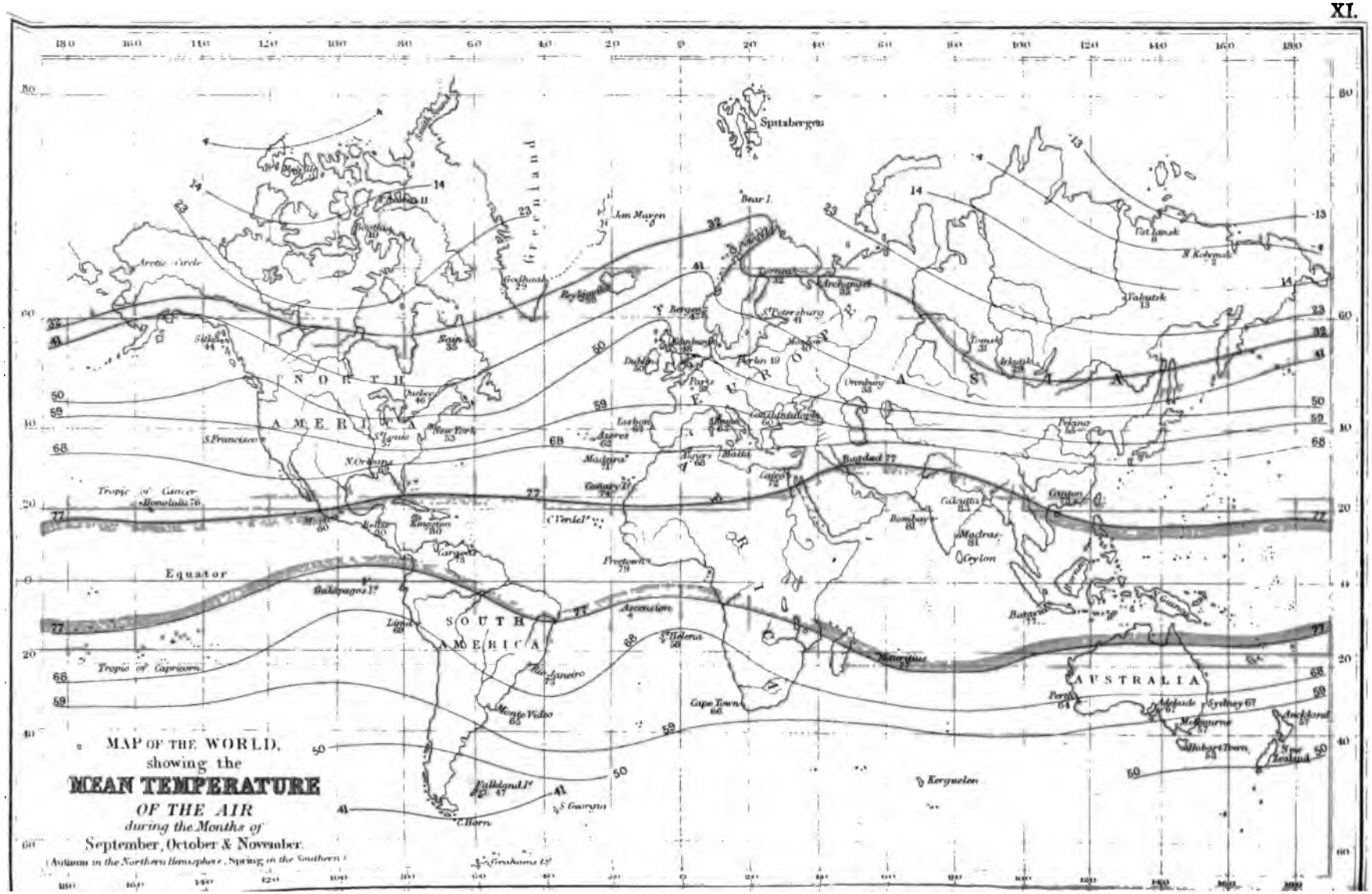

80
70
60
50
40
10
0
CARIBBEAN SEA
NORTH ATLANTIC OCEAN
SOUTH AMERICA
Trinidad
Barbados
St Vincent
Grenada
Lake of Maracaybo
Gulf of Darien
Gulf of Panama
Gulf of Guayaquil
Cayenne
Maraca I.
C. do Norte
Fernando Noronha I.
Ilhas de Maraja
Pernambuco
Todos Santos B.
Abrolhos Is
Galapagos Is
Malpelo I.
C. Blanco
C. San Roque
Ross I.
Meziana I.
Caviana I.
Orinoco
Amazon
Andes
Cordill. Real
Selvas or Forest Plains of the Amazon
Pampas del Sacramento
Llanos
Parima
Tumucumaque Mts
Serra Geral
Serra do Espinhaço
Serra do Mar
Serra dos Aymores
Serra dos Vertentes
Serra Mantiqueira
Serra dos Pyreneos
Serra Dourada
Serra Parecis
Serra Acary
Serra Tapajos
Serra Tumucumaque
Serra Parima
Serra Pacaraima
Serra Grande
Serra Tucuma
Serra Uassary
Serra Tabatinga
Serra Cupim
Serra Ibiapaba
Serra Borborema
Serra Araripe
Serra Chapada
Serra Pacaas Novos
Serra Ricco
Serra Aguapehy
Serra Maracaju
Serra Amambay
Serra Caaguazu
Serra Mbaracayu
Serra Yabebyry
Serra Tape
Serra Monte Grande
Serra Monte Negro
Serra Monte Alegre
Serra Monte Caseros
Serra Monte Video
Serra Monte Santo
Serra Monte Pascoal
Serra Monte Serrat
Serra Monte Christo
Serra Monte Verde
Serra Monte Azul
Serra Monte Claro
Serra Monte Alto
Serra Monte Bello
Serra Monte Formoso
Serra Monte Grande
Serra Monte Negro
Serra Monte Alegre
Serra Monte Caseros
Serra Monte Video
Serra Monte Santo
Serra Monte Pascoal
Serra Monte Serrat
Serra Monte Christo
Serra Monte Verde
Serra Monte Azul
Serra Monte Claro
Serra Monte Alto
Serra Monte Bello
Serra Monte Formoso



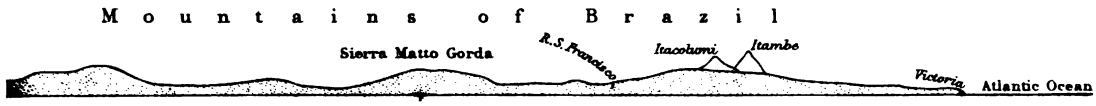
William Collins Sons & Co. London & Glasgow


PHYSICAL MAP OF THE
BRITISH ISLES
Explanation.
The lines round the Coast thus ——— indicate the line of 50 Fathoms depth. ——— 100 Fathoms.
The figures in the Ocean the ascertained depth at those points (in fathoms) ——— The figures attached to the Mountains &c. their height above the Sea, in feet.
Highlands. Brown. Lowlands. Green.
BY
EDWD WELLER. FRGS
SHETLAND ISLANDS
ORKNEY ISLANDS
Pentland Firth
C. Wrath
Little Minch
Sound of Barra
Barra Hd.
Coll
Tiree
Firth of Forth
Moray Firth
Solway Firth
Malin Hd.
St Abbs Hd.
Buchan Ness
Kinnaird Head
Duncansby Hd.
Dunnet Head
Tarbet Ness
Fair I.
Foula
Westra
Rousay
Stronsa
Hoy
Sanda
Papinsha
N. Ronaldsha
S. Ronaldsha
Flannan I.
St Kilda
Borera
Pabbay
S. Uist
Benbecula
N. Uist
Barra
Eriskay
Wateray
Rum
Eigg
Canna
Sulisker
Iona
Mull of Kintyre
Islay
Jura
Colonsay
Oronsay
Ben More
Ben Nevis
Ben Cruachan
Ben Lomond
Ben Ledi
Ben Vorlich
Ben Lawers
Ben Macdui
Cairngorm
Ben Nevis
Schiehallion
Ben Wyvis
Morven
Mayen Bill
Aberdeen
Montrose
Arbroath
Dundee
Perth
Stirling
Forth of Tay
Fife Ness
May I.
Holy I.
Berwick
Tweed
Solway
Loch Ness
Loch Lomond
Loch Tay
Loch Rannoch
Loch Katrine
Loch Awe
Loch Fyne
Loch Etive
Loch Leven
Loch Maree
Loch Shin
Loch Broom
Loch Inver
Loch Eriboll
Loch Erisort
Loch Roag
Loch Seaforth
Loch Tarbert
Loch Indaal
Loch Gruinard
Loch Torridon
Loch Carron
Loch Alsh
Loch Hourn
Loch Nevis
Loch Morar
Loch Shiel
Loch Eil
Loch Linnhe
Loch Leven
Loch Creran
Loch Etive
Loch Awe
Loch Fyne
Loch Long
Loch Goil
Loch Striven
Loch Ryan
Loch Indaal
Loch Gruinard
Loch Torridon
Loch Carron
Loch Alsh
Loch Hourn
Loch Nevis
Loch Morar
Loch Shiel
Loch Eil
Loch Linnhe
Loch Leven
Loch Creran
Loch Etive
Loch Awe
Loch Fyne
Loch Long
Loch Goil
Loch Striven
Loch Ryan
OCEAN
NORTH
SEA


I R I S H S E A
E N G L I S H C H A N N E L
Bristol Channel
Cardigan Bay
Liverpool Bay
Caernarvon B.
Dublin B.
Galway B.
Donegal B.
Dundalk B.
Lambay I.
Howth Hd.
Holy I.
Wicklow Hd.
Arran Is.
Achil I.
The Mullet
Isle of Man
Flamborough Hd.
Spurn Hd.
Morecambe Bay
Walney I.
St. Bees Hd.
Solway Firth
Mull of Galloway
Chicken Rock
Lundy I.
Hartland Pt.
Trevose Hd.
Lyme Bay
Portland Bill
St. Alban's Hd.
Start Pt.
Bolt Hd.
Falmouth H.
C. Cornwall
Scilly Is.
Lizard Hd.
Land's End
Mounts B.
St. Davids Hd.
St. Brides B.
Milford Haven
St. Govans Hd.
Caermarthen B.
Worms Hd.
Swansea B.
Smalls L.
Tuskar
Carnsore Pt.
Saltee Is.
Wexford H.
Cahore Pt.
Tremadoc B.
Braich-y-Pwll
The Wrekin
Cleveland Hills
Burringham Pt.
The Wash
Orfordness
The Naze
Foulness
Sheppey I.
Thames
London
Dungeness
Beachy Hd.
Selsea Bill
I. of Wight
Needles
Strait of Dover
Channel Is.
Dunkerry B.
Barnstaple B.
Brown Wy
Dartmoor
Plymouth
Tor Bay
Exeter
Taunton
Bridgwater
Severn R.
Bristol
Salisbury
Portsmouth
Southampton
Dorchester
Weymouth
Poole
Christchurch
Bournemouth
Lymington
Newport
Ryde
Cowes
Shanklin
Ventnor
Yarmouth
Hurst Castle
Selsey
Chichester
Arundel
Brighton
Lewes
Hastings
Rye
Dungeness
Ashford
Canterbury
Margate
Ramsgate
Deal
Dover
Folkestone
Sandwich
Whitstable
Faversham
Sittingbourne
Rochester
Gravesend
Tilbury
Southend
Sheerness
Harwich
Felixstowe
Ipswich
Aldeburgh
Lowestoft
Yarmouth
Cromer
Sheringham
Wells
Hunstanton
Boston
Spalding
Peterborough
Ely
Cambridge
Bedford
Luton
Hertford
Watford
Reading
Oxford
Aylesbury
Banbury
Coventry
Warwick
Leamington
Worcester
Gloucester
Cheltenham
Tewkesbury
Evesham
Stratford
Hereford
Ross
Monmouth
Chepstow
Newport
Cardiff
Penarth
Barry
Bridgend
Swansea
Neath
Port Talbot
Llanelly
Caermarthen
Tenby
Milford
Haverfordwest
Fishguard
Cardigan
Aberystwith
Barmouth
Harlech
Portmadoc
Pwllheli
Caernarvon
Bangor
Conway
Llandudno
Rhyl
Denbigh
Ruthin
Wrexham
Chester
Flint
Holyhead
Anglesea
Skerries
Carnsore Pt.
Tuskar
Wicklow
Arklow
Wexford
Waterford
Dungarvon
Youghal
Cork Harbr.
Old Hd. of Kinsale
Cape Clear
Mizen Hd.
Bantry
Dursey Hd.
Valentia
Dingle B.
Brandon Hd.
Slyne Hd.
Aughrus Hd.
Inishbofin
Inishark
Clare Is.
Achil Sd.
Killybegs
Teelin
Slieve League
Donegal B.
Sligo
Killala B.
Broad Haven
Belmullet
Erris Hd.
Blacksod B.
Clew B.
Galway B.
Kilkieran B.
Arran Is.
Inishmore
Inishmaan
Inishere
Kerry Hd.
Loop Hd.
Shannon
Kilrush
Tarbert
Foynes
Limerick
Askeaton
Adare
Tralee
Killarney
Mallow
Fermoy
Cork
Youghal
Dungarvon
Waterford
Carnsore Pt.
Saltee Is.
Wexford
Arklow
Wicklow
Wicklow Hd.
Howth Hd.
Lambay I.
Dublin
Kingstown
Dalkey
Bray
Wicklow
Arklow
Gorey
New Ross
Waterford
Dungarvon
Youghal
Cork Harbr.
Old Hd. of Kinsale
Cape Clear
Mizen Hd.
Bantry
Dursey Hd.
Valentia
Dingle B.
Brandon Hd.
Slyne Hd.
Aughrus Hd.
Inishbofin
Inishark
Clare Is.
Achil Sd.
Achil I.
The Mullet


MAP OF THE WORLD,
showing the
MEAN TEMPERATURE
OF THE AIR
during the Months of
September, October & November.
(Autumn in the Northern Hemisphere, Spring in the Southern.)
NORTH AMERICA
SOUTH AMERICA
EUROPE
ASIA
AFRICA
AUSTRALIA
Spitzbergen
Greenland
Iceland
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Jan Mayen
Bear I.
Archangel
St Petersburg
Berlin
Paris
Dublin
Madrid
Malta
Azores
Canary Is
Cairo
Baghdad
Calcutta
Bombay
Madras
Ceylon
Canton
Pekin
Yakutsk
Tobolsk
Orenburg
Irkutsk
Tomsk
Nain
Quebec
New York
S. Francisco
Honolulu
Mexico
Kingston
Caracas
Galapagos Is
Lima
Rio Janeiro
Monte Video
Cape Town
St Helena
Ascension
Fernando
Mauritius
Bengal
Perth
Adelaide
Sydney
Melbourne
Hobart Town
Auckland
New Zealand
Kerguelen
Falkland Is
C. Horn
Graham's Is
C. Verde Is
Trinidad
Barbadoes
Jamaica
Bermuda
Gibraltar
Malta
Azores
Madeira
Canary Is
Cape Verde Is
Galapagos Is
Ascension
St Helena
Mauritius
Kerguelen
Falkland Is
Graham's Is

E R I C A



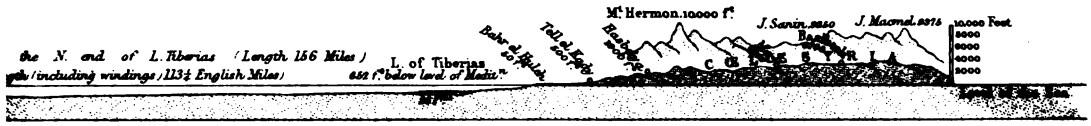
c to the Pacific

I S L E S



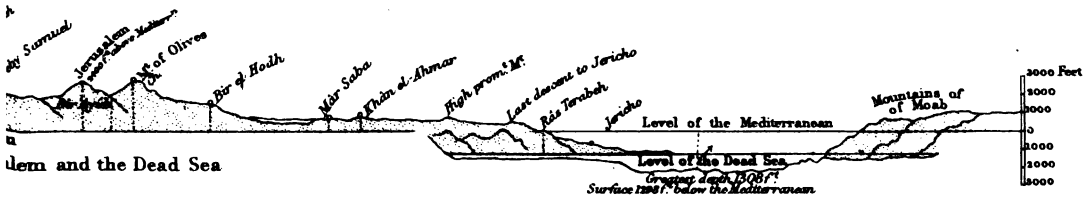
ı to Beachy Head

T I N E



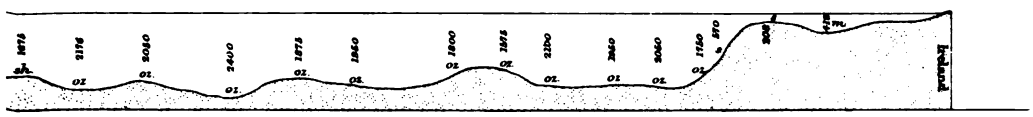
l depression of the Holy Land

T I N E



lem and the Dead Sea

T I C O C E A N

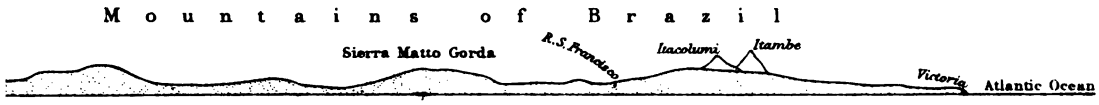


Bay. Newfoundland, on the Scale of 1 Vertical - 30 Horizontal

IX.

Engraved by Edw.d Wellan, Red Lion Sqre, London.

M E R I C A



.c to the Pacific

I S L E S



h to Beachy Head

T I N E



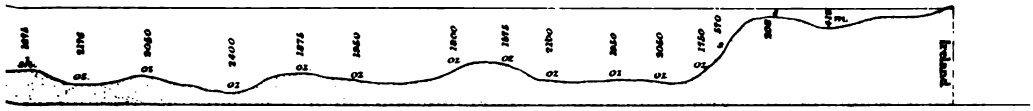
l depression of the Holy Land

T I N E



alem and the Dead Sea

T I C O C E A N



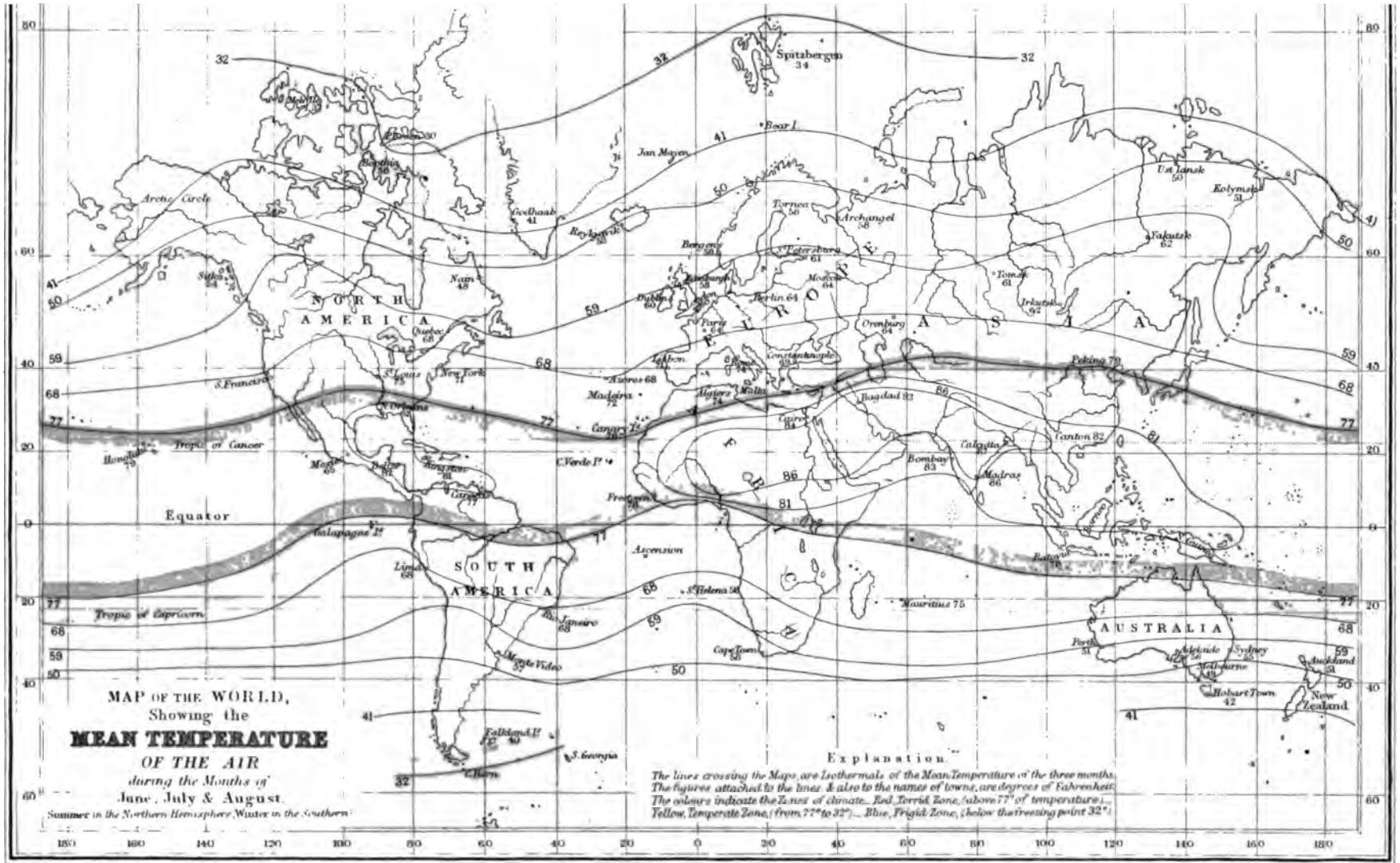
r Bay, Newfoundland on the Scale of 1 Vertical - 30 Horizontal

IX.

Engraved by Edwd. Wallen, Red Lion Sqre. London.

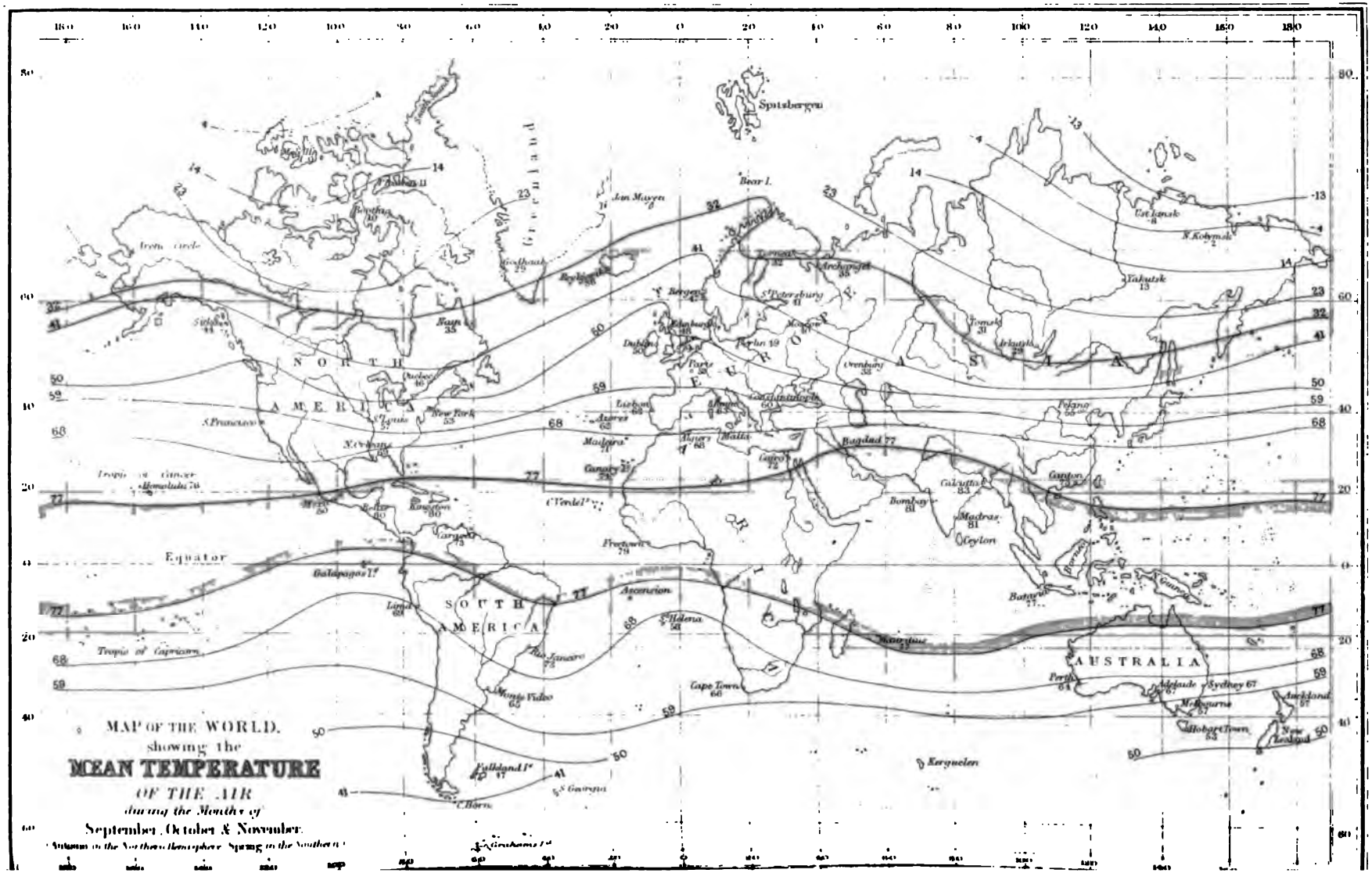


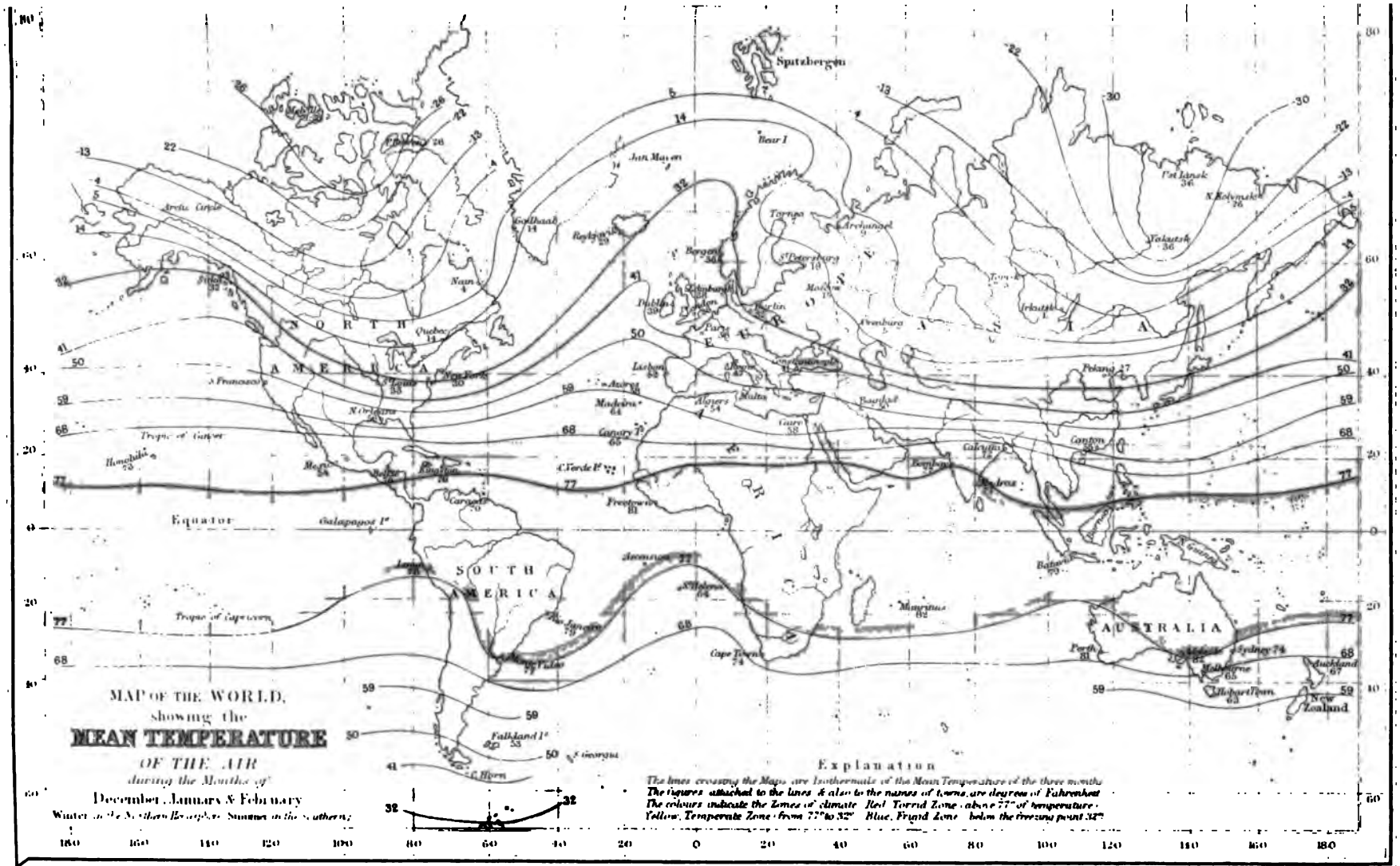
Diagram showing the elevation of the Snow Line in different Latitudes



William Collins, Sons & Co. London & Glasgow.

Edwd Weller, F.R.G.S., Red Lion Sqa. London.

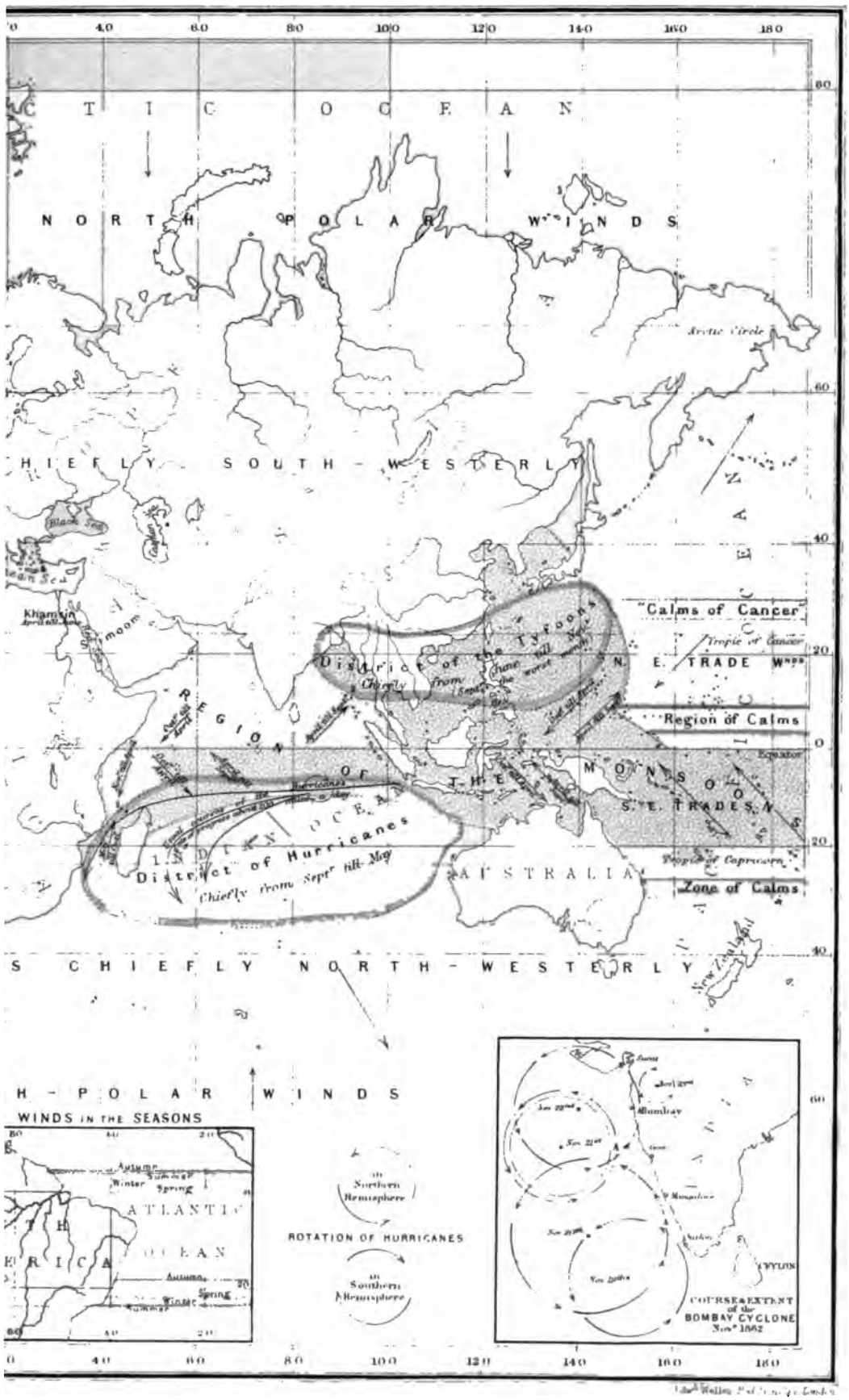

MAP OF THE WORLD,
showing the
MEAN TEMPERATURE
OF THE AIR
during the Months of
September, October & November.
Autumn in the Northern Hemisphere. Spring in the Southern
NORTH AMERICA
SOUTH AMERICA
EUROPE
ASIA
AUSTRALIA
Spitsbergen
Bear I.
Jan Mayen
Iceland
Archangel
St Petersburg
Moscow
Yakutsk
Ust Lensk
N. Kolymsk
Tomsk
Irkutsk
Orenburg
Berlin
Dublin
Paris
Lisbon
Madeira
Azores
Malta
Cairo
Bagdad
Canary Is
Cape Verd Is
Bombay
Madras
Ceylon
Calcutta
Canton
Galapagos Is
Lima
Ascension
St Helena
Rio Janeiro
Monte Video
Cape Town
Falkland Is
C. Horn
Kerguelen
Perth
Adelaide
Sydney
Melbourne
Hobart Town
Auckland
New Zealand
Equator
Tropic of Cancer
Tropic of Capricorn
Arctic Circle
Antarctic Circle
Greenwich



Edwd Weller F.R.G.S. Red Lion Sq. London

William Collins, Sons & Co. London & Glasgow


MAP OF THE WORLD
Showing the Distribution of
CONSTANT, PERIODICAL, & VARIABLE
WINDS
BY
EDWD WELLER. F.R.G.S.
The point of the Arrow indicates the direction towards which the wind blows.
REGION OF PREVAIL
REGION OF VARIABLE WI
NORTH
AMERICA
Zone of Calms
"Calms of Cancer"
REGION OF THE NORTH EAST
TRADE WINDS
Mean Extent of Region of Calms (Doldrums)
& frequent Thunder Storms
Galapagos Is.
REGION OF THE SOUTH EAST
TRADE WIN
SOUTH
AMERICA
Zone of Calms. "Calms of Capricorn"
Zone of
Pamperos
REGION OF VARIABLE
REGION OF PREVAILING
LIMITS OF THE NORTH EAST TRADE WINDS IN THE SEASONS
North America
South America
ATLANTIC
OCEAN
LIMITS OF THE SO
PACIFIC
OCEAN


C T I C O C E A N
N O R T H P O L A R W I N D S
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
CHIEFLY SOUTH - WESTERLY
CHIEFLY NORTH - WESTERLY
"Calms of Cancer"
E. TRADE Winds
Region of Calms
S.E. TRADES
Zone of Calms
AUSTRALIA
Black Sea
Khamsin
Monsoon
District of the Typhoons
Chiefly from June till Nov.
REGION OF THE MONSOONS
INDIAN OCEAN
District of Hurricanes
Chiefly from Sept. till May
WINDS IN THE SEASONS
Autumn
Winter
Spring
Summer
ATLANTIC
OCEAN
ROTATION OF HURRICANES
in Northern Hemisphere
in Southern Hemisphere
Bombay
Ceylon
COURSE & EXTENT of the BOMBAY CYCLONE June 1862

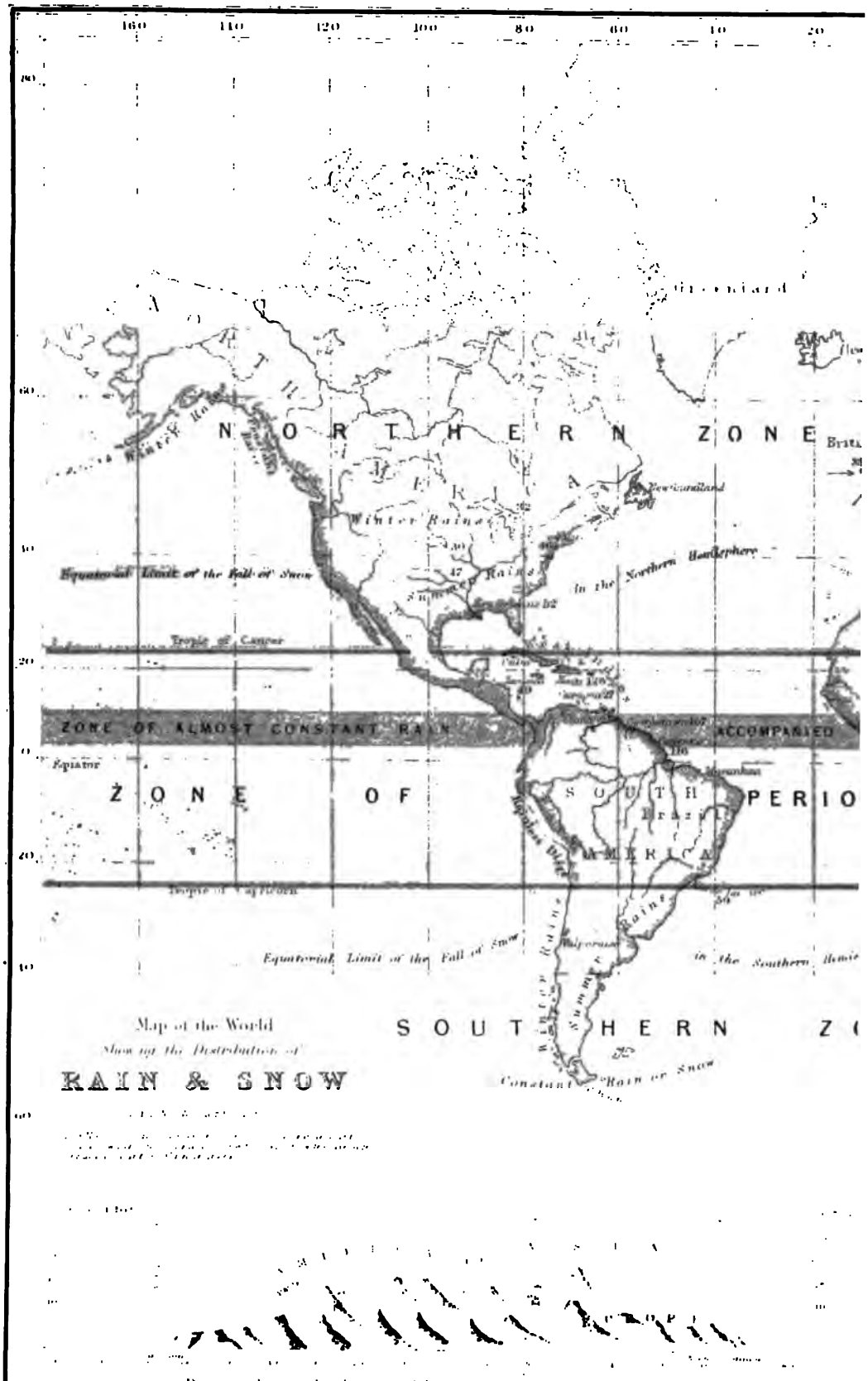
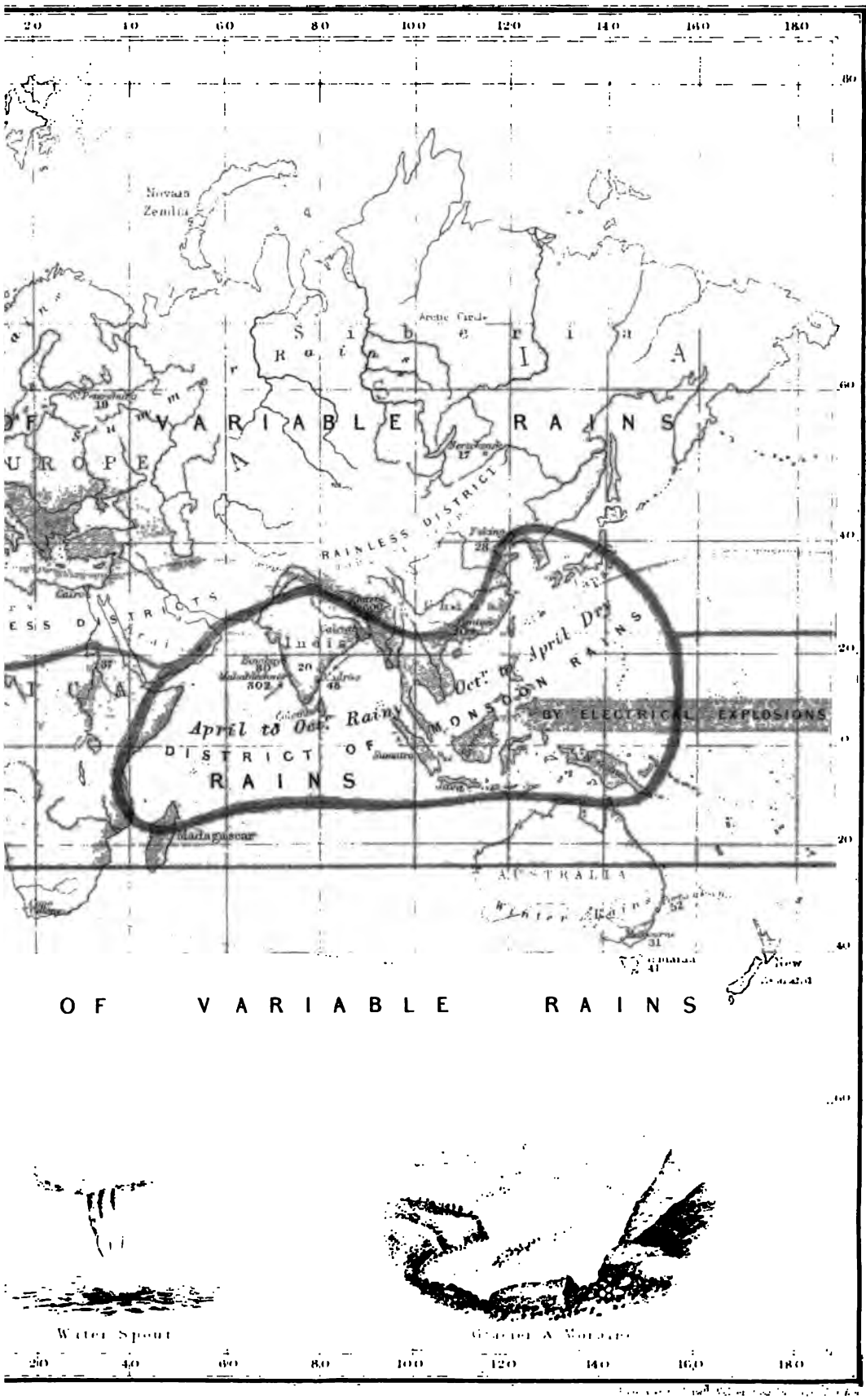
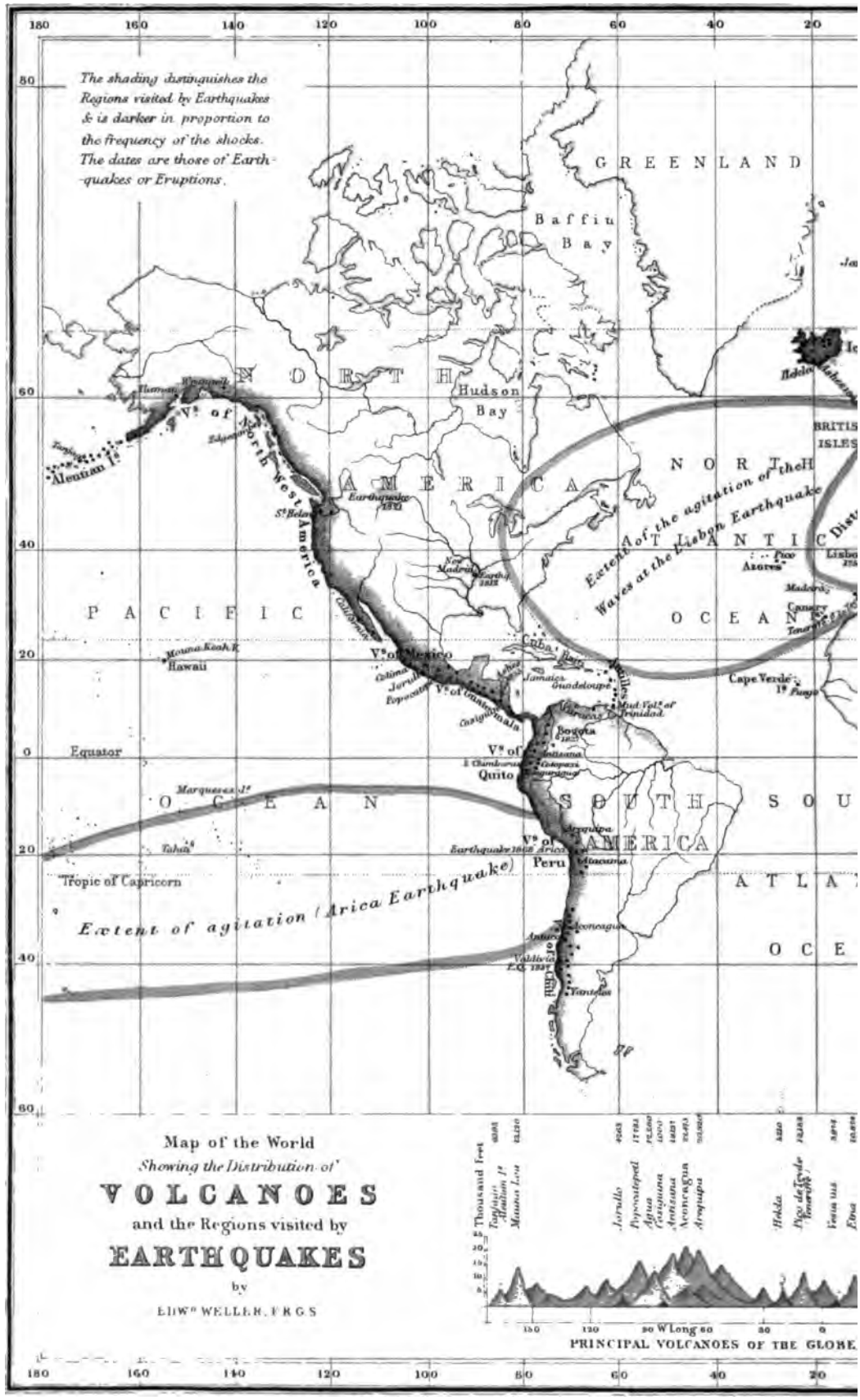
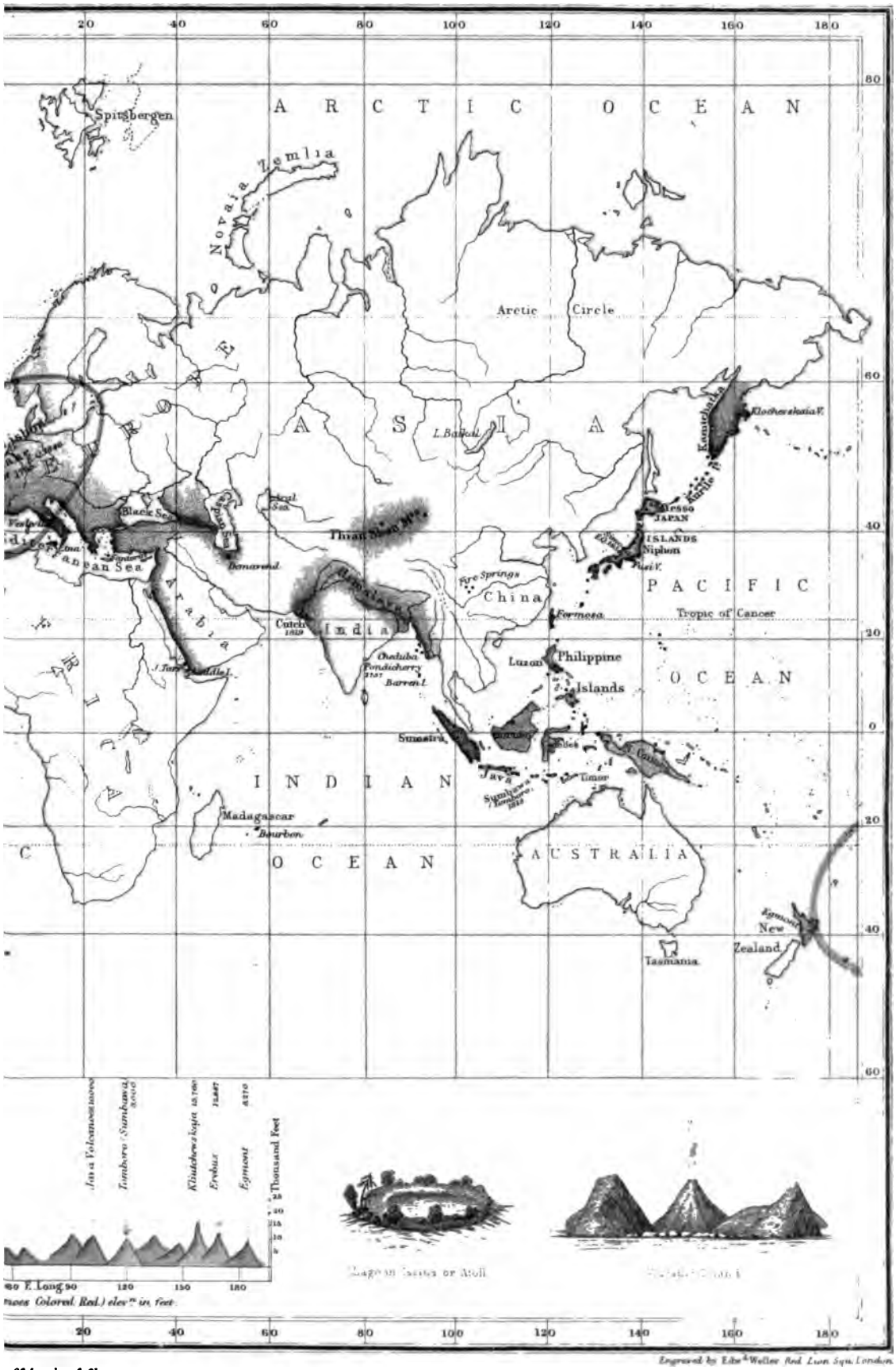


Diagram showing the elevation of the Snow Line in different Latitudes

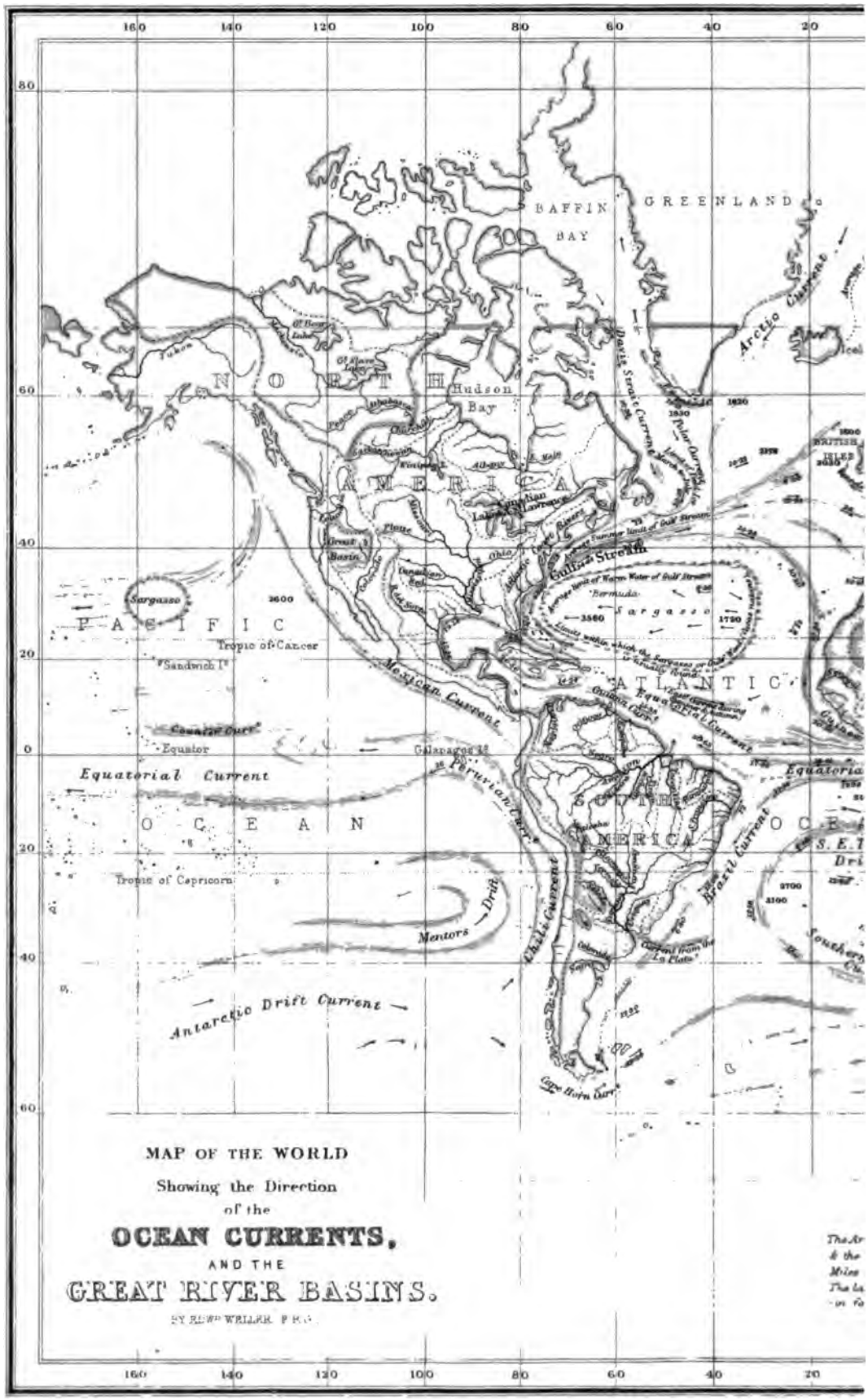


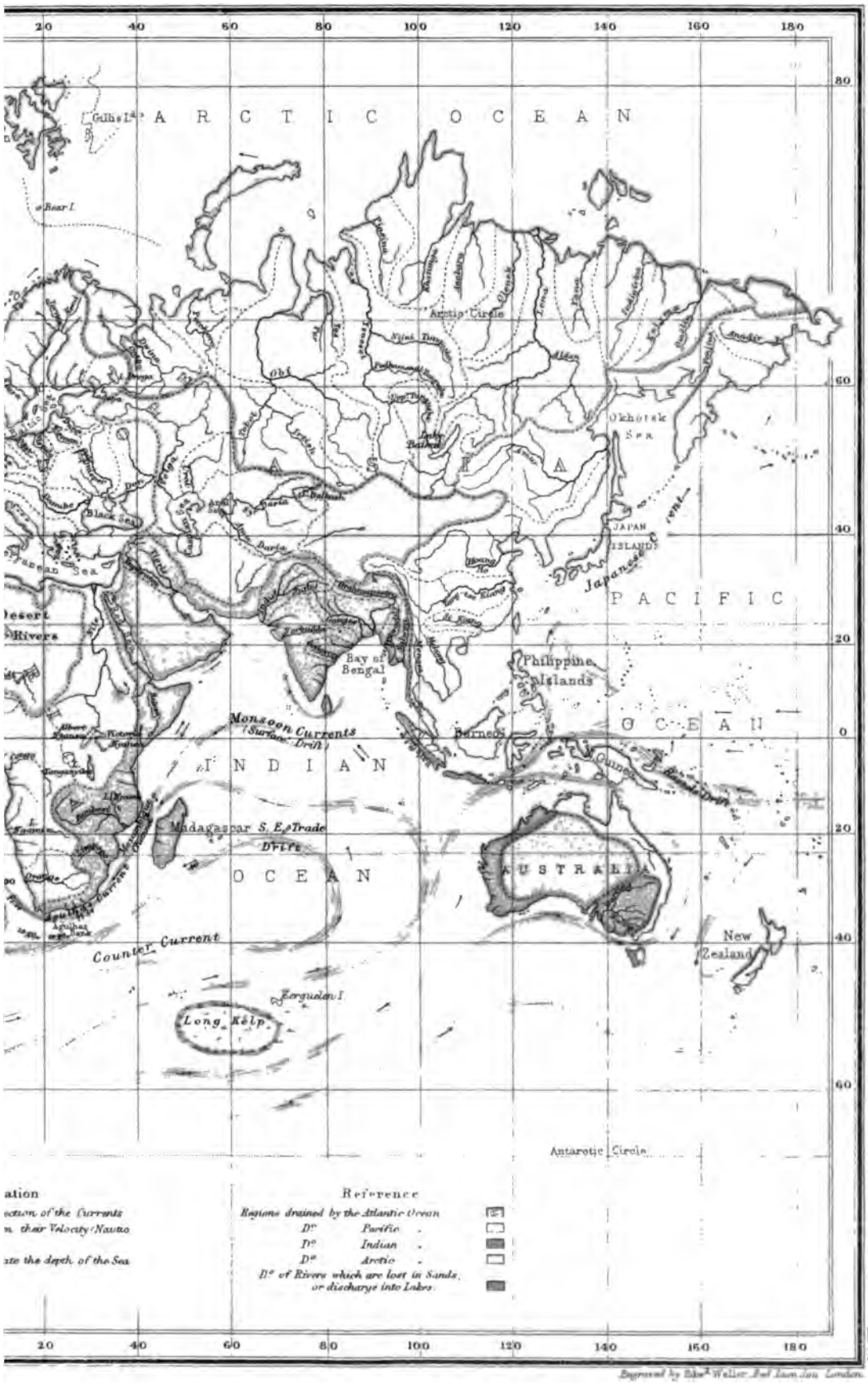
OF VARIABLE RAINS


The shading distinguishes the Regions visited by Earthquakes & is darker in proportion to the frequency of the shocks. The dates are those of Earthquakes or Eruptions.
GREENLAND
Baffin Bay
NORTH AMERICA
Hudson Bay
PACIFIC OCEAN
ATLANTIC OCEAN
SOUTH AMERICA
Equator
Tropic of Capricorn
Extent of the agitation of the Lisbon Earthquake
Extent of agitation (Arica Earthquake)
Map of the World
Showing the Distribution of
VOLCANOES
and the Regions visited by
EARTHQUAKES
by
EDWD WELLER, F.R.G.S.
PRINCIPAL VOLCANOES OF THE GLOBE



- C.° London & Glasgow

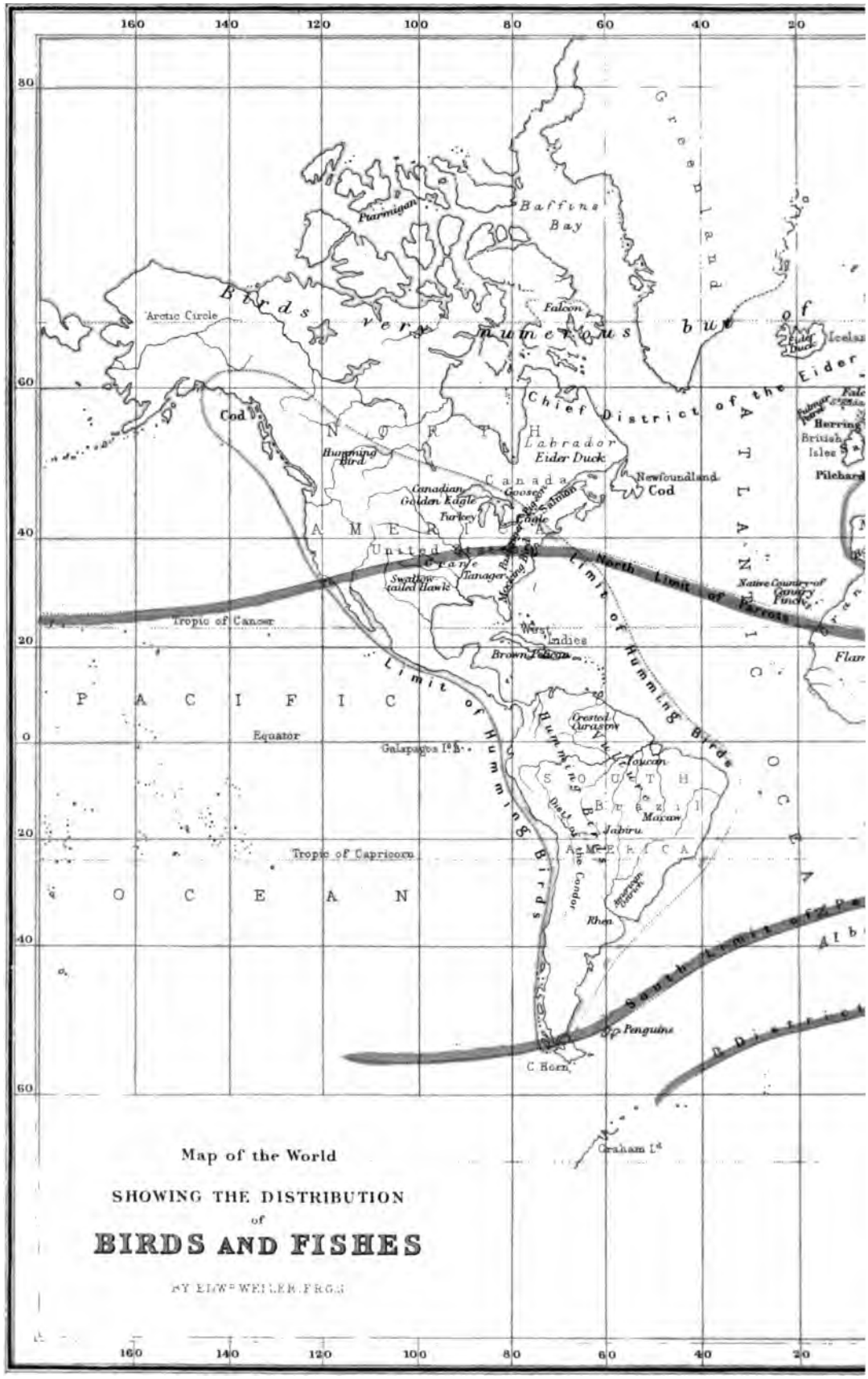

160
140
120
100
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60
BAFFIN BAY
GREENLAND
NORTH AMERICA
Hudson Bay
Arctic Current
Davis Strait
Current
Gulf of Mexico
Gulf Stream
Sargasso Sea
Bermuda
Sargasso
PACIFIC OCEAN
Tropic of Cancer
Sandwich I.
Mexican Current
Equator
Galapagos Is.
Equatorial Current
Peruvian Current
ATLANTIC OCEAN
Equatorial Current
SOUTH AMERICA
Tropic of Capricorn
Mentors Drift
Brazil Current
Chile Current
Antarctic Drift Current
Cape Horn Current
MAP OF THE WORLD
Showing the Direction
of the
OCEAN CURRENTS,
AND THE
GREAT RIVER BASINS.

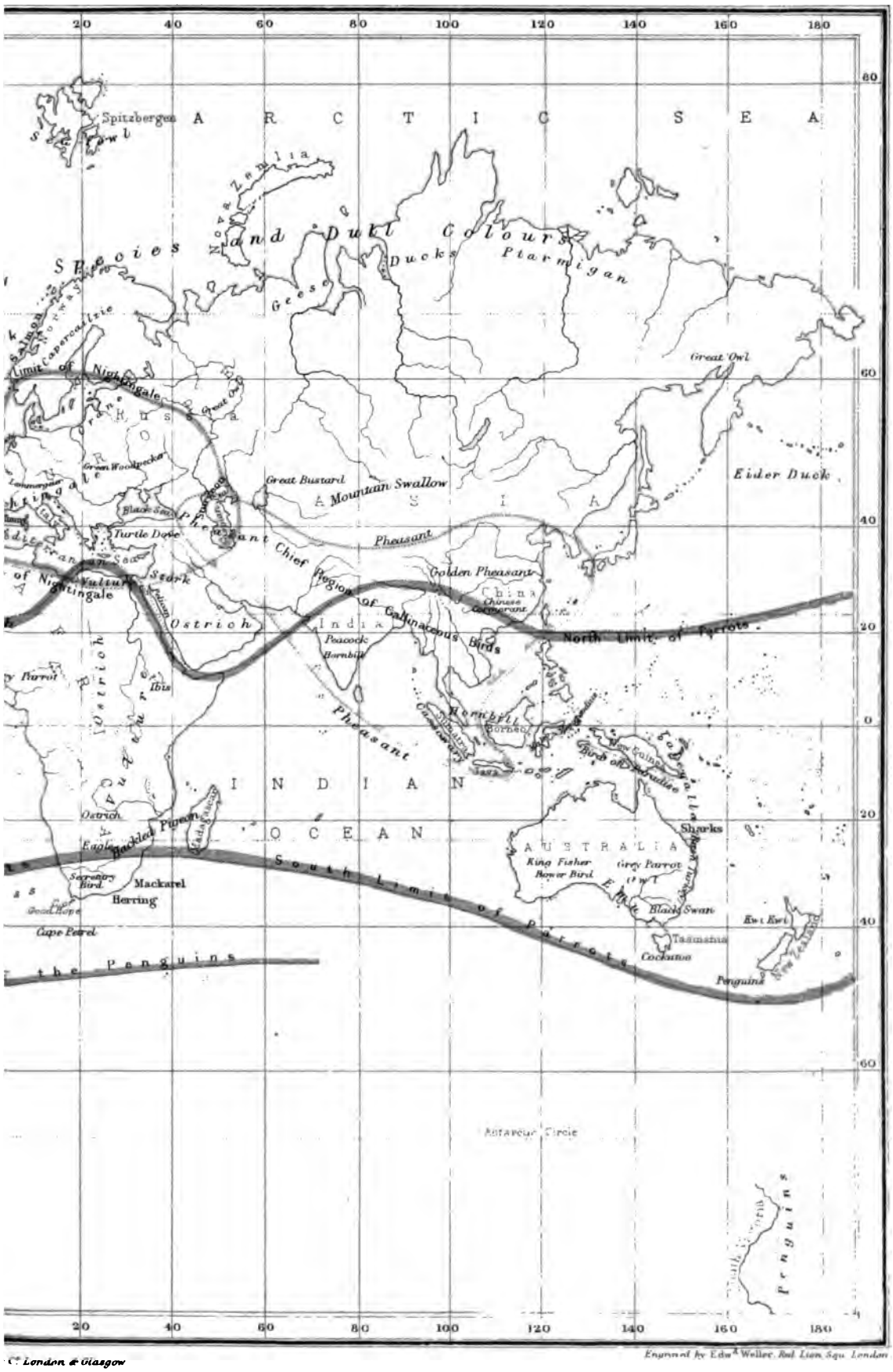


XV.

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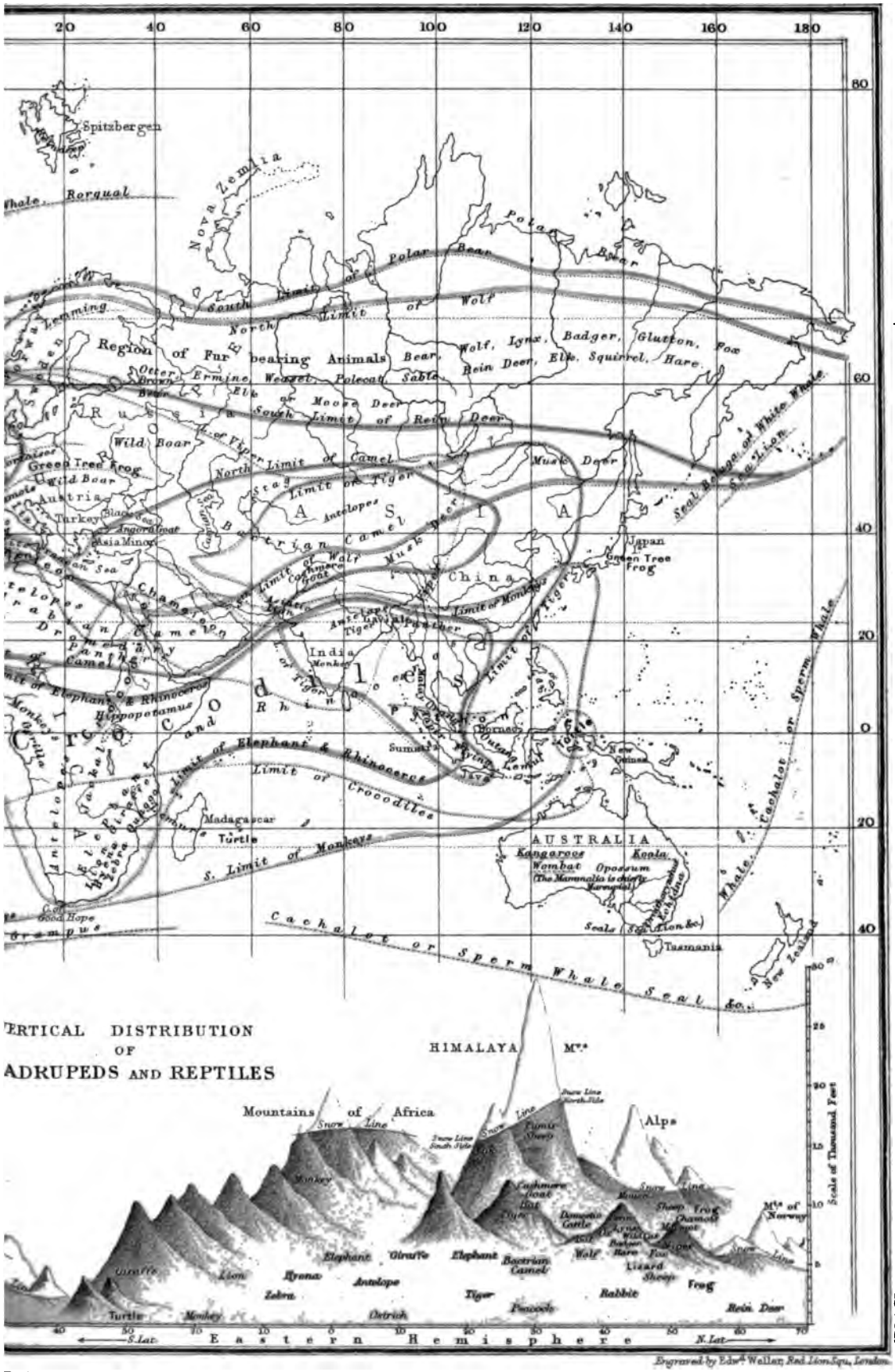

Map of the World
SHOWING THE DISTRIBUTION
of
BIRDS AND FISHES
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Limit of Humming Birds
North Limit of Parrots
South Limit of Penguins
Ptarmigan
Baffins Bay
Greenland
Falcon
Eider Duck
Chief District of the Eider
Cod
Labrador
Humming Bird
Canada
Newfoundland
Canadian Goose
Golden Eagle
Turkey
Eagle
Salmon
Herring
Pilchard
Native Country of Canary Birds
Mocking Bird
Swallow tailed Hawk
Manager
West Indies
Brown Falcon
Crested Curassow
Toucan
Macaw
Jabiru
Rhea
Condor
Galapagos Is.
C. Horn
Graham L.d
PACIFIC OCEAN
ATLANTIC OCEAN
NORTH AMERICA
SOUTH AMERICA
United States



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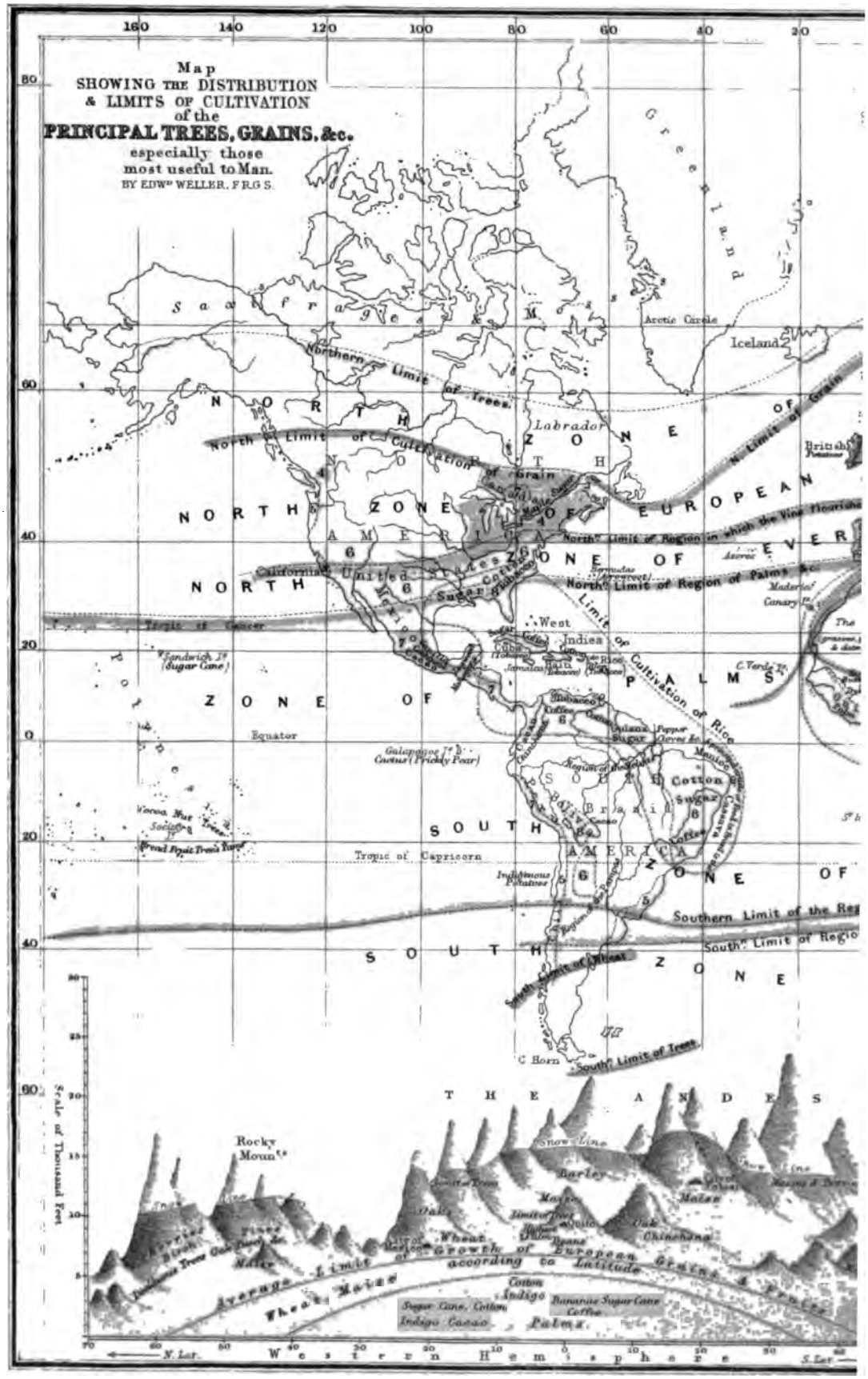

Map Showing the
GEOGRAPHICAL DISTRIBUTION
of
QUADRUPEDS, REPTILES &c.
BY EDWD WELLER, F.R.G.S.
160
140
120
100
80
60
40
20
80
60
40
20
0
20
40
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Greenland
Baffins Bay
Hudson Bay
Labrador
Canada
United States
AMERICA
Mexico
West Indies
Galapagos Is.
Elephant Tortoise
Iguana
C Horn
Region of Fur Bearing Animals
Polar Bear
Arctic Fox
Musk Ox
Reindeer
Lemming
Wolf
Lynx
Hare
Musk Rat
Beaver
Otter
Marten
Badger
Fox
Moose
Elk
Grizzly Bear
Black Bear
Raccoon
Skunk
Opossum
Armadillo
Puma
Jaguar
Rattlesnake
Crocodile
Boa
Monkeys
Tapir
Llama
Vicuna
Agouti
Vampire Bat
Whale
Seal
Walrus
Narwhal
Porpoise
Limit of Reptiles
Limit of Crocodiles
Limit of Monkeys
Limit of Tortoises
Frogs
Scale of Thousand Feet
Rocky Mts
THE ANDES
Snow Line
Western Hemisphere
N. Lat.
S. Lat.

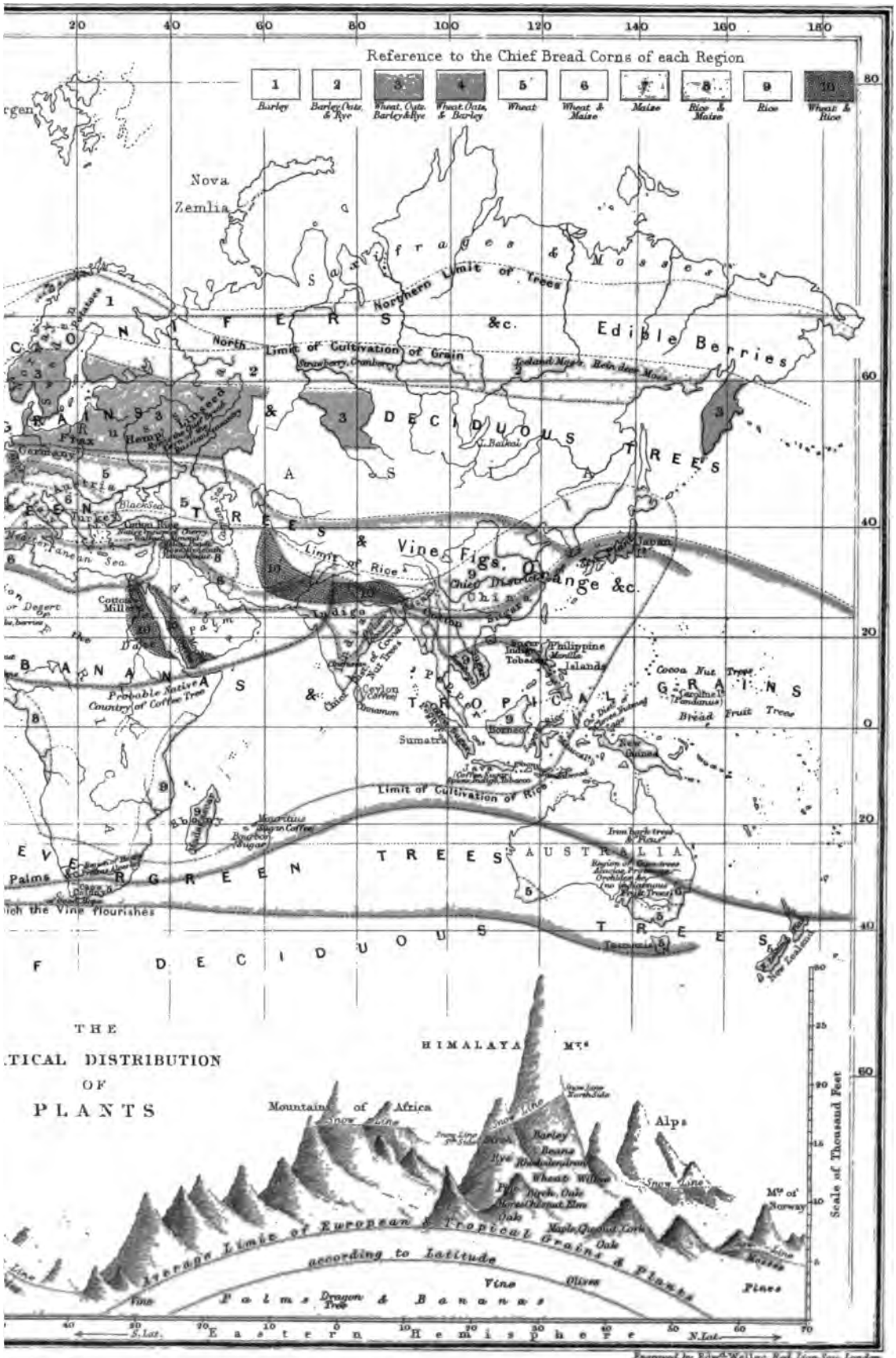


ERTICAL DISTRIBUTION
OF
ADRUPEDS AND REPTILES

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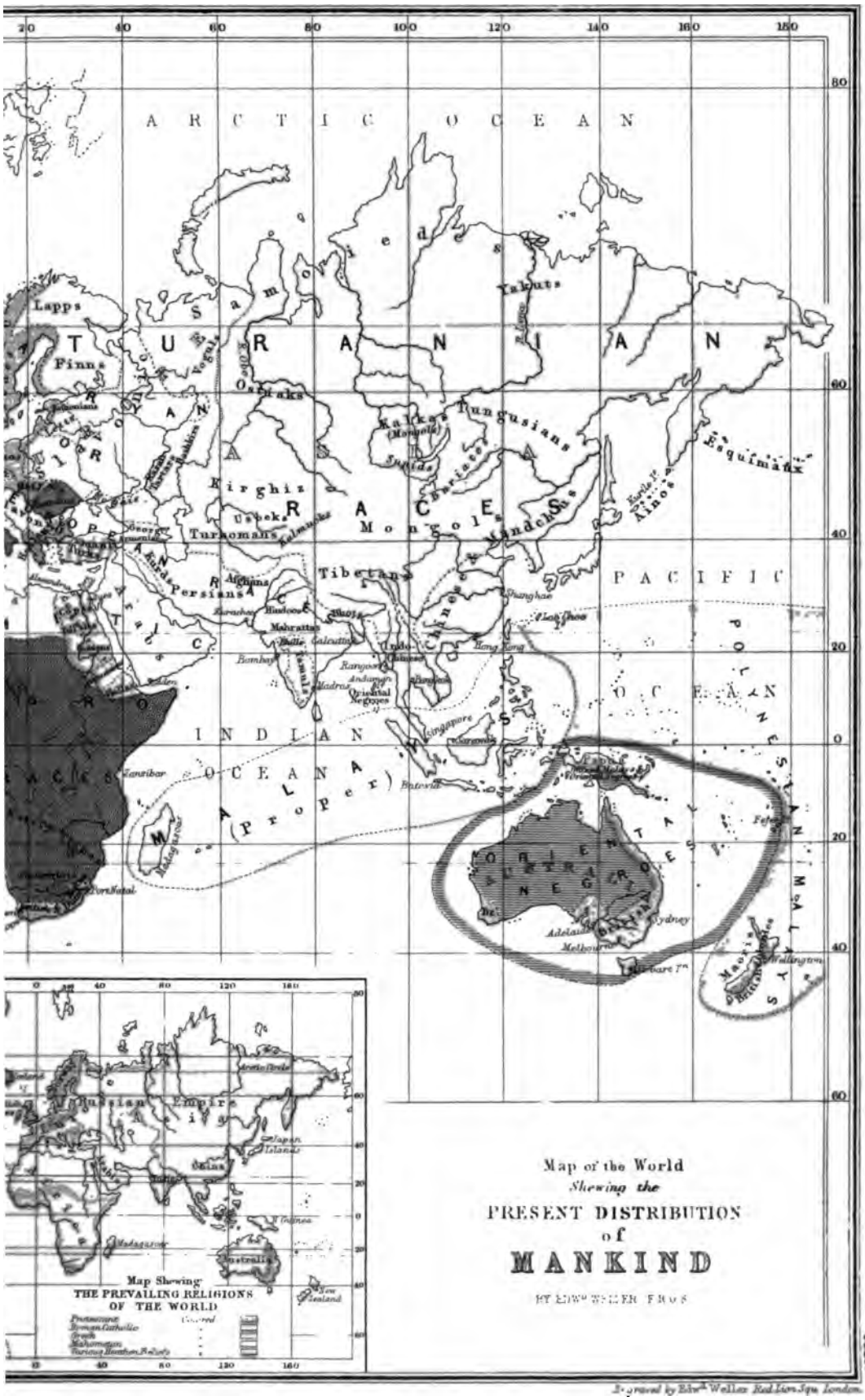

Map
SHOWING THE DISTRIBUTION
& LIMITS OF CULTIVATION
of the
PRINCIPAL TREES, GRAINS, &c.
especially those
most useful to Man.
BY EDWD WELLER, F.R.G.S.
Greenland
Arctic Circle
Iceland
Labrador
Northern Limit of Trees.
North Limit of Cultivation of Grain
N. Limit of Grain
British
NORTH ZONE OF EUROPEAN
NORTH AMERICA
North Limit of Region in which the Vine flourishes
NORTH ZONE OF EVER
California
United States
Cotton
Sugar
Mexico
North Limit of Region of Palms &c.
Madeira
Canary Is.
Tropic of Cancer
West Indies
Limit of Cultivation of Rice
PALMS
Sandwich Is.
(Sugar Cane)
C. Verde Is.
ZONE OF
Equator
Galapagos Is.
Cactus (Prickly Pear)
Tobacco
Coffee
Cocoa
Indian Corn
Sugar
Pepper
Cloves &c.
Manioc
SOUTH
Brazil
Cotton
Sugar
Coffee
Cocoa
Vanilla
Pepper
Cloves
Nutmegs
Ginger
Rice
Sweet Potatoes
Yams
Maize
Tropic of Capricorn
SOUTH AMERICA
ZONE OF
Indigenous Potatoes
Southern Limit of the Region
South Limit of Region
SOUTH ZONE
South Limit of Wheat
C. Horn
South Limit of Trees
THE ANDES
Rocky Mountains
Snow Line
Barley
Maize
Oats
Oak
Chinchona
Wheat
Growth of European Grains according to Latitude
Average Limit of Wheat & Maize
Cotton
Indigo
Bananas
Sugar Cane
Coffee
Cocoa
Palms
Scale of Thousand Feet
N. Lat.
Western Hemisphere
S. Lat.



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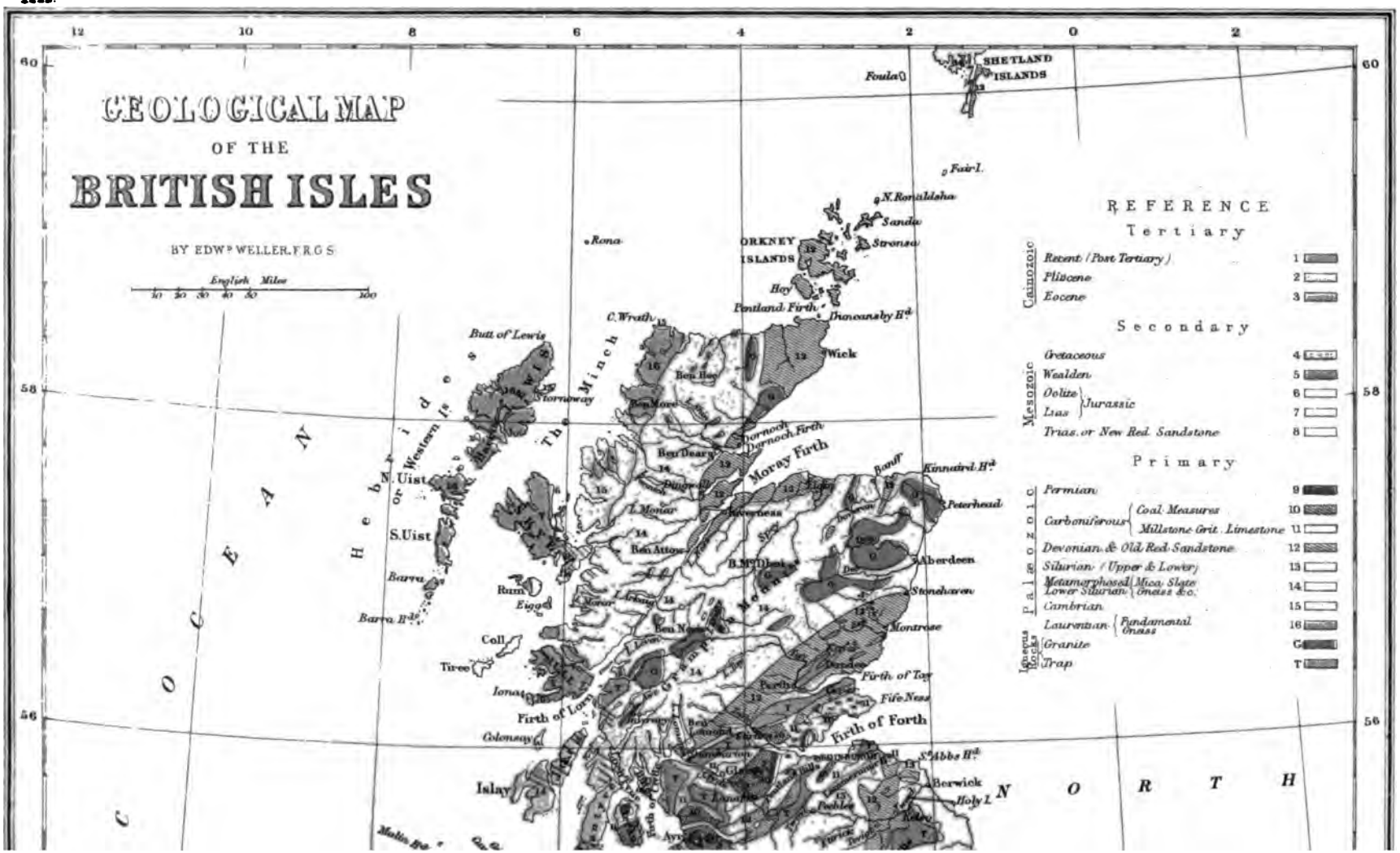
William Collins

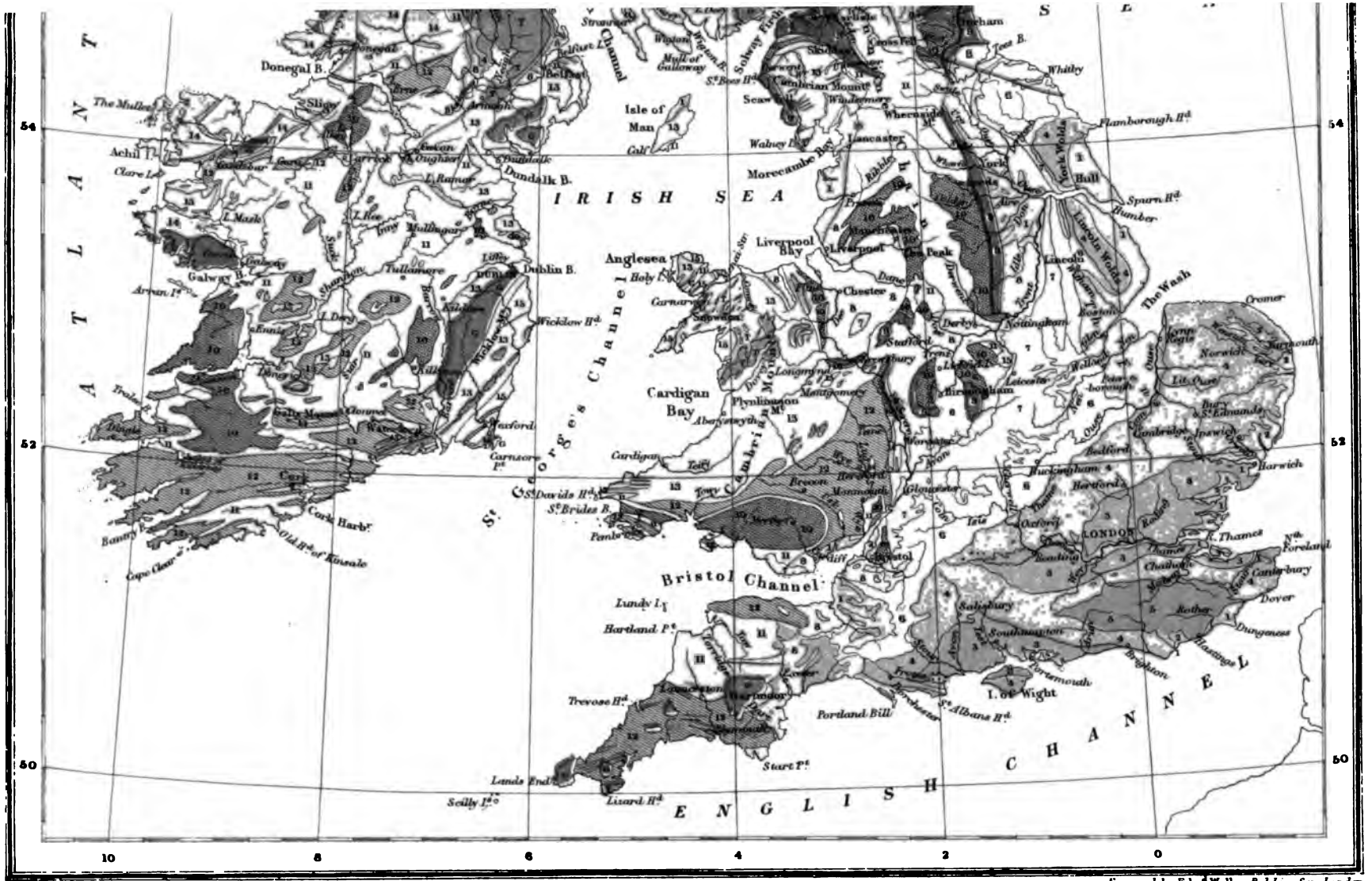


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XIX

Ranyon.


GEOLOGICAL MAP
OF THE
BRITISH ISLES
BY EDWD WELLER, F.R.G.S.
English Miles
0 10 20 30 40 50 100
SHETLAND ISLANDS
Foula
Fair I.
N. Ronaldsha
Sanda
Stronsa
Rona
ORKNEY ISLANDS
Hoy
Pentland Firth
Duncansby Hd
C. Wrath
Butt of Lewis
Wick
Ben Hee
Stornoway
The Minch
Ben More
Dornoch
Dornoch Firth
Ben Dearg
Moray Firth
Banff
Kinnaird Hd
Peterhead
N. Uist
Western Isles or Hebrides
L. Morar
Aberdeen
S. Uist
Ben Attow
Stonehaven
Barra
Barra Hd
Rum
Eigg
Montrose
Coll
Tiree
Firth of Tay
Iona
Fife Ness
Firth of Lorn
Firth of Forth
Colonsay
St Abbs Hd
Islay
Berwick
Holy I.
Mull
Ayr
OCEAN
NORTH
REFERENCE
Tertiary
Cainozoic
Recent (Post Tertiary) 1
Pliocene 2
Eocene 3
Secondary
Mesozoic
Cretaceous 4
Wealden 5
Oolite } Jurassic 6
Lias } 7
Trias or New Red Sandstone 8
Primary
Palæozoic
Permian 9
Carboniferous { Coal Measures 10
Millstone Grit Limestone 11
Devonian & Old Red Sandstone 12
Silurian (Upper & Lower) 13
Metamorphosed Lower Silurian { Mica Slate Gneiss &c. 14
Cambrian 15
Laurentian { Fundamental Gneiss 16
Igneous Rocks
Granite G
Trap T



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5 Physical Map of North America—shewing as above.
6 Physical Map of South America—shewing as above.
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17 Map of the World—shewing the Geographical Distribution of Quadrupeds and Reptiles.
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12 Hispania.
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17 Egypt.

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